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Long Term Results of Pancreatectomy With and Without Venous Resection: A Comparison of Safety and Complications of Spiral Graft, End-to-End and Tangential/Patch Reconstruction Techniques

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WHAT THIS PAPER ADDS

This is the largest study yet published comparing the short and long term outcomes for different venous reconstruction techniques together with radical intent pancreatic resection. The technique of spiral interposition graft from the patient's own great saphenous vein was standardised for use in pancreatectomy when longer venous resections were needed. This retrospective study aimed to determine its safety and feasibility.

Objective: Roughly 10% — 20% of pancreatic cancer patients are candidates for curative intent surgical treatment. In the 2000s, many studies showed similar survival rates comparing pancreatic surgery with or without vein resection and reconstruction. The aim was to identify the best method of venous reconstruction.
Methods: This was a retrospective cohort study. A total of 1 375 patients undergoing pancreatectomy between 2005 and 2018 were identified. Patients undergoing a combined pancreatic resection and venous reconstruction were included retrospectively. When tumour infiltration to the portal/superior mesenteric vein was detected, excision and reconstruction with tangential suturing/patch, end to end anastomosis, or a spiral graft from the great saphenous vein was performed. Next, 90 day and long term survival and outcomes across reconstruction techniques were analysed.
Results: Overall, 198 patients had venous involvement visible in pre-operative scans or detected during surgery, broken down as follows: 171 (86%) pancreaticoduodenectomy, 12 (6%) total pancreatectomy, and 15 (8%) distal pancreatectomy. In total, 69 (35%) spiral graft reconstructions, 77 (39%) end to end anastomoses, and 52 (26%) tangential/patch reconstructions were performed. Tumour histology revealed pancreatic adenocarcinomas in 162 (82%) patients, intraductal mucinous pancreatic neoplasia in 14 (7%), cholangiocarcinoma in five (3%), neuroendocrine neoplasia in nine (5%), and eight other diagnoses. Overall, 183 (92%) were malignant and 15 (8%) benign. Two patients died within 90 days, one in hospital and one on post-operative day 38 due to thrombosis of the superior mesenteric vein and intestinal necrosis, a Clavien—Dindo grade 5 complication. In addition, 50 (23%) patients had Clavien—Dindo grade 3 — 4 complications. No differences in complications comparing vein reconstruction techniques or in the long term survival of pancreatectomy patients with or without venous reconstruction were detected.
Conclusion: The spiral graft technique, used when more advanced venous infiltration occurs, does not increase complications, with outcomes mirroring those accompanying shorter venous resections.

Keywords: Vascular surgery, Spiral graft, Pancreatic surgery, Portal vein, Superior mesenteric vein
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INTRODUCTION

Pancreatic cancer has one of the worst prognoses among malignant diseases.[1—3] Despite broad international efforts in the surgical and oncological fields, no remarkable advances have emerged in the survival of pancreatic cancer patients. Operative treatment combined with oncological therapies remain the best chance for cure among patients diagnosed with pancreatic cancer, including when the tumour has

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invaded vascular structures.[4] Vascular invasion should no longer be regarded as a sign of non-resectable disease, and pancreatic resection combined with a vascular resection and reconstruction has been shown as worthwhile among borderline resectable pancreatic tumours.[5–7] However, pancreatic surgery carries a high risk of post-operative complications, and vascular resections have increased the risk in the past. Post-operative complication rates have decreased as these resections have become more common.[7,8]

Portal vein (PV) and superior mesenteric vein (SMV) resections and reconstructions are currently a routine part of pancreatic cancer surgery. Survival rates after margin negative pancreatic cancer surgery combined with PV–SMV resections have become almost identical in terms of survival after operations without vein resections.[5,6]

In particular, when the resection is > 3 cm in length the use of interposition grafts is widely accepted.[9] For instance, in 2015 a Swedish study group showed that after a Cattell–Braasch manoeuvre it is feasible to perform an end to end anastomosis between the PV and the SMV.[10] Yet in larger series this technique has been accompanied by acute thrombosis of the PV–SMV, especially when the resection has exceeded 3 cm.[9]

Synthetic interposition grafts have been associated with a higher number of acute thrombosis cases and reduced survival.[11,12] Since 1997 the technique for PV–SMV interposition with a custom spiral graft taken from the great saphenous vein (GSV) has been used. The aim here was to analyse the safety and results of the spiral GSV interposition graft compared with other techniques used during pancreatic surgery.

PATIENTS AND METHODS

Patient selection and pre-operative planning

All 1 375 patients undergoing elective pancreatic surgery between 2005 and 2018 were identified from a Helsinki University Hospital database. Patient diagnoses were heterogeneous as shown in Table 1. In addition to pancreaticoduodenectomy patients, distal and total pancreatectomies were also included in the analysis. At Helsinki University Hospital, pancreatic neoplasms with suspected vascular involvement were evaluated for surgery as part of a specialised multidisciplinary team, which included a radiologist, an oncologist, pancreatic surgeons, and an endoscopic retrograde cholangiopancreatography specialised surgeon if needed. Vascular involvement was detected either by pre-operative computed tomography (CT) or by a surgeon intra-operatively, and the vascular surgical team was pre-warned, informed, and involved as soon as this information was available. Cases involving the distal branches of the mesenteric veins or portal invasion close to the liver hilum were evaluated as part of an oncovascular meeting to evaluate the more difficult reconstruction possibilities. Vascular resection and reconstruction were performed during pancreatic surgery if the tumour was infiltrating the PV or SMV. The type of reconstruction used was decided upon by the vascular surgeon intra-operatively. Lateral suturing was occasionally performed by pancreatic surgeons. Patients with arterial resections were excluded from this study.

Table 1. Demographic characteristics of 198 patients undergoing pancreatectomy and venous reconstruction between 2005 and 2018 in a single centre, divided by type of venous repair

Patient demographics	All (n=198)	Spiral graft (n=69)	End-to-end (n=77)	Tangential/Patch (n=52)	p
Sex					
Female	90 (45)	25 (36)	42 (55)	23 (44)	
Male	108 (55)	44 (64)	35 (45)	29 (56)	.086
Age – y	67 (19–81)	67 (45–77)	67 (39–80)	67 (51–79)	1.0
ASA					
1	22 (11)	5 (7)	9 (12)	8 (15)	
2	66 (33)	25 (36)	27 (35)	14 (27)	
3	101 (51)	36 (52)	38 (49)	27 (52)	
4	9 (5)	3 (4)	3 (4)	3 (6)	.79
Procedure					
Pancreaticoduodenectomy	171 (86)	60 (87)	69 (90)	42 (81)	
Distal resection	15 (8)	4 (6)	4 (5)	7 (14)	
Total pancreatectomy	12 (6)	5 (7)	4 (4)	3 (6)	.44
Diagnose					
Benign	15 (8)	4 (6)	6 (8)	5 (10)	
Malignant	183 (92)	65 (94)	71 (92)	47 (90)	.70
Adenocarcinoma	162 (82)	57 (83)	61 (79)	44 (85)	
IPMN	14 (7)	7 (10)	7 (9)	0	
Neuroendocrine neoplasia	9 (5)	0	4 (5)	5 (10)	
Cholangiocarcinoma	5 (3)	1 (1)	4 (5)	0	
Other	8 (4)	4 (6)	1 (1)	3 (6)	.007
*Radical resection**					
Yes	88 (60)	35 (67)	27 (50)	26 (67)	.81
No	57 (39)	17 (33)	27 (50)	13 (33)	

Data are presented as n (%) or median (range), unless stated otherwise.
*Only cases with pancreatic ductal adenocarcinoma were included in the analysis; data missing for 17 patients. ASA = American Association of Anesthesiologists; IPMN = intraductal pancreatic mucinous neoplasia.

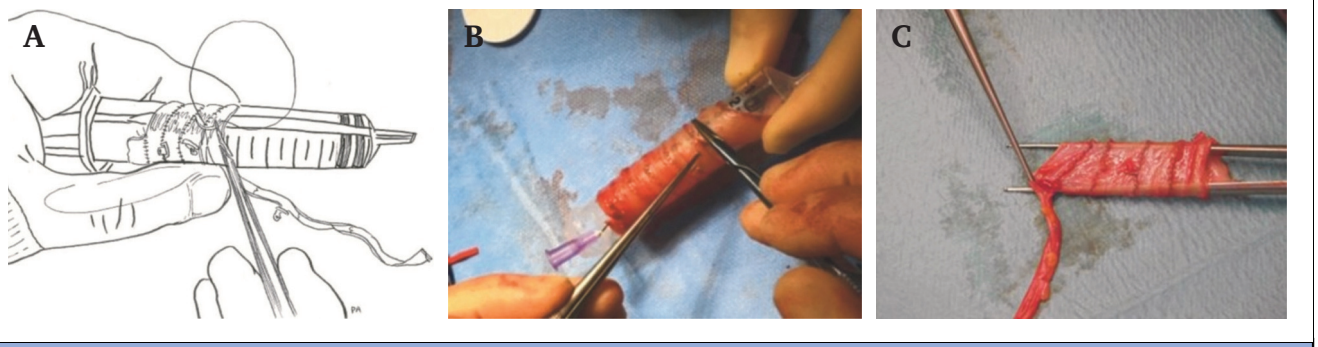

Figure 1. (A, B) Representation of the technical preparation of a spiral venous graft using the great saphenous vein, with the aid of a 5 or 10 mL syringe and (C) end result with extra vein for subsequent lengthening if needed.

Surgical technique

The resection allowed lateral suturing when the main venous trunk circumference reduction was estimated as a maximum of 30%, but a low threshold for vascular consultation was preferred. The suture material was 5-0 or 6-0 polypropylene. A patch reconstruction was considered when suturing would have narrowed the PV or SMV too much by visual and intra-operative ultrasound estimation. The patch material used was either a bovine pericardium or autologous vein graft, according to the vascular surgeon's preference. If the reduction of the vein circumference was more than 30% and the required resection was less than 2 — 3 cm, an end to end anastomosis was performed. An interposition graft was used if the anastomosis seemed too long (> 3 cm) for an end to end anastomosis. Pre-operative ultrasound assessment of both GSVs was performed, with the better one used, normally from the thigh area. In this patient cohort, both GSVs were unusable in only one patient, for whom a cephalic vein was used instead. Other conduits, such as the jugular vein, basilic vein, left renal vein, or femoral veins, were not used in this series. The GSV was harvested, the side branches were ligated, the vein was split open longitudinally, and the valves resected under visual control. The autograft was sutured around a 5 or 10 mL syringe with 6-0 polypropylene depending on the estimated diameter of the resected vein. The PV/SMV clamp time was kept to a minimum to avoid intestinal oedema. This was achieved by preparing the spiral graft while dissecting the tumour until only the vein resection remained. The graft was anastomosed end to end first to the SMV, then the retractors were released in order to control the correct length of the graft, and then an end to end PV anastomosis was performed. Sometimes the SMV branches were first sutured together in order to create a single lumen proximal anastomosis with the graft. The splenic vein was anastomosed end to side to the graft, if applicable, without further exposure or a risk of kinking to increase the portal vein flow (see Figs. 1 and 2). The portal flow was controlled with a transit time flow measurement and later in the series (*circa* 2015 onwards) the reconstruction was routinely visualised by intra-operative ultrasound. Patients were fully heparinised and monitored with an activated clotting time (ACT), for a target of 200 — 300 seconds. The standard minimum anticoagulation used in all of the procedures was post-operatively administered prophylactic doses of low molecular weight heparin (LMWH) for a four week period.

Pancreatectomy technique

An *en bloc* resection of the tumour, pancreas, duodenum, bile duct, and distal part of the stomach, the affected

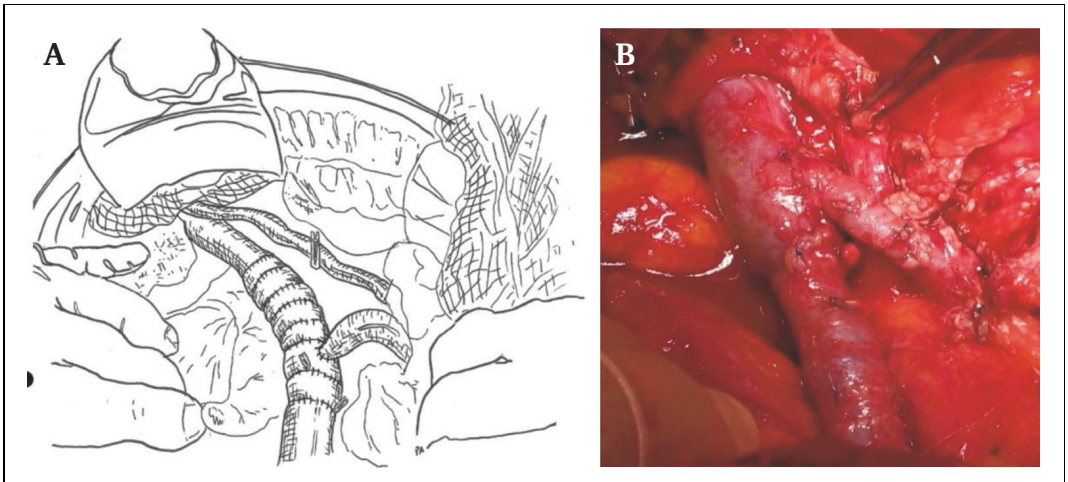

Figure 2. Visual representation of the splenic vein sutured (A) to the side of the graft and (B) to the side of the portal vein.

venous segment, and surrounding structures, including the soft tissue and lymph nodes, was performed. Pancreaticoduodenectomy and distal gastrectomy were performed using a Billroth II reconstruction. Pancreatic reconstruction was performed with duct to mucosa sutures to the jejunal loop. Hepaticojejunostomy was performed using 5-0 interrupted sutures. In a distal pancreatectomy, the pancreatic main duct was closed by suturing or with a stapler depending upon the operating surgeon. A radical resection, R0, was considered if post-operative pathological resection margins exceeded 1 mm.

Outcome analysis

The primary outcome was 30 day death. Secondary outcomes were severe complications according to Clavien–Dindo classification grades 3 – 5 90 days post-operatively.[13] From all 198 venous reconstruction procedures, post-operative thromboembolic events, re-operations and non-planned days needed in the intensive care unit (ICU) were recorded. There was no routine follow up imaging defining the post-operative patency of the grafts used. Pancreatectomy specific complications and pancreatic fistula rates were analysed according to the International Study Group of Pancreatic Fistulae criteria,[14–16] while post-operative chyle leak, post-pancreatectomy haemorrhage, and delayed gastric emptying (DGE) were analysed according to the International Study Group of Pancreatic Surgery criteria.[17–19] Bile leak was categorised according to an international consensus statement.[20] Post-pancreatectomy haemorrhage was considered grade A if the serum haemoglobin value exceeded 30 g/L after surgery and grade B if blood products were administered to the patient.[17] The pancreatic texture or main duct diameter were not recorded systematically during this study. Further analysis of complications was performed for patients who underwent a pancreaticoduodenectomy together with a venous reconstruction. Long term survival was analysed in patients undergoing a pancreaticoduodenectomy comparing the results with patients undergoing a vascular reconstruction. Survival of patients with a R0 resection was compared with survival after resection with a margin of less than 1 mm (R1).

In this analysis, a spiral graft was compared with end to end anastomosis, tangential suture, or patch resections. The chi squared test, Kruskal–Wallis test, and the Fisher exact test were used, whereby $p < .050$ was considered statistically significant. Multivariable analysis with a logistic regression model was used to calculate the relationship between different events following surgery.

RESULTS

In total, 1 375 patients underwent pancreatic surgery between January 2005 and December 2018. Among them, 230 (17%) had a vascular resection and reconstruction, either arterial, venous, or combined. Venous reconstruction as the only vascular procedure was performed in 198 (86%) patients, with pancreaticoduodenectomy performed in 171 (86%), total pancreatectomy in 12 (6%) and distal resection in 15 (8%). The reconstruction technique used was a spiral graft from the GSV in 69 (35%) patients, end to end anastomosis in 77 (39%), and tangential or a patch reconstruction in 52 (26%). Tumour histology revealed adenocarcinoma in 162 (82%) patients, intraduct mucinous pancreatic neoplasia in 14 (7%), cholangiocarcinoma in five (3%), neuroendocrine neoplasia in nine (5%), and eight other diagnoses (papillary or duodenal neoplasia or pancreatitis). Malignant diseases were identified in 183 (92%) patients and benign 15 (8%). Table 1 summarises the patient demographic characteristics. Arterial reconstruction or both artery and vein reconstruction were performed in 32 cases (14%) , which were excluded from further analysis.

Post-operative complications

Clavien–Dindo (CD) grade 3 – 5 complications occurred in 20 (29%) patients in the spiral graft group, 18 (23%) in the end to end group and 14 (27%) in the tangential/patch group, ($p = .44$). Table 2 summarises the CD grading of complications. The logistic regression model of complications for different surgical techniques appears in Table 3.

There were eight (4%) portal or SMV thromboses: two (3%) in the spiral graft group, four (5%) in the end to end group and two (4%) in tangentially sutured group ($p = .78$). Other post-operative thromboembolic events, pulmonary or peripheral, occurred in six (3%) patients. Thrombotic events were managed with LMWH, 1 mg/kg twice daily, injections for a minimum of four weeks. No complications associated with elevated portal vein pressure were observed in this study.

Thrombotic events in portomesenteric or lienal veins were analysed long term up to three years after surgery. Eleven late thrombotic events, three months post-operatively, occurred during the study, all of them associated with disease progression. One thrombotic event occurred six months post-operatively, six during the first year and four during the second year after surgery. No statistical differences were seen between thrombotic events and venous reconstruction techniques, $p = .66$. The overall risk of venous thromboembolic events for patients undergoing a pancreatectomy due to

Table 2. Post-operative complications according to the Clavien–Dindo classification in 198 patients undergoing pancreatectomy and venous reconstruction between 2005 and 2018 in a single centre, without showing significant differences between groups ($p = .44$). Grades 3–5 considered serious complications, with grade 5 indicating death

	0	1	2	3	4	5
Spiral graft	7 (10)	17 (25)	25 (36)	17 (25)	3 (4)	0
End-to-end	6 (8)	18 (23)	35 (46)	9 (12)	7 (9)	2 (3)
Tangential/Patch	8 (15)	12 (23)	18 (35)	10 (19)	4 (8)	0
Total	21 (11)	47 (24)	78 (40)	36 (18)	14 (7)	2 (1)

Data are presented as *n* (%).

Table 3. Logistic regression models of the risk of Clavien–Dindo grade 3–5 complications in 198 patients undergoing pancreatectomy and venous reconstruction between 2005 and 2018

Variables	Univariable		Multivariable*	
	OR (95% CI)	*p*	OR (95% CI)	*p*
Study arm				
Spiral graft	1		1	
End-to-end	0.747 (0.356–1.568)	.44	0.786 (0.367–1.680)	.53
Tangential/Patch	0.903 (0.404–2.016)	.80	0.876 (0.385–1.995)	.75
Sex				
Female/male	0.608 (0.317–1.166)	.13	0.662 (0.339–1.293)	.23
Diagnosis				
Malignant/benign	0.373 (0.128–1.085)	.070	0.409 (0.136–1.224)	.11
Age	0.981 (0.948–1.016)	.29	0.989 (0.954–1.025)	.54

CI = confidence interval; OR = odds ratio.
* No significant interactions were found after adjusting with the Bonferroni correction for multiple comparisons.

Table 4. Post-operative complications according to vein reconstruction technique in 198 patients undergoing pancreatectomy and venous reconstruction between 2005 and 2018, divided by type of venous repair

	All (*n*=198)	Spiral graft (*n*=69)	End-to-end (*n*=77)	Tangential/Patch (*n*=52)	*p*
Portal or superior mesenteric vein thrombosis	8 (4)	2 (3)	4 (5)	2 (4)	.78
Post-pancreatectomy haemorrhage†					
None	102 (52)	32 (46)	45 (44)	25 (25)	
Grade A	49 (25)	20 (29)	13 (17)	16 (31)	
Grade B	43 (22)	16 (23)	16 (21)	11 (21)	
Grade C	4 (2)	1 (1)	3 (4)	0	.34
Re-operation*	14 (7)	5 (7)	8 (10)	1 (2)	.18

Data are presented as *n* (%).
* See detailed information in the results section.
† For explanations of Grades, please refer to Outcome analysis in the Methods section.

cancer are analysed in a another article; the patients partly overlap with this current series.[21]

A total of 14 (7%) patients underwent a re-operation. Two re-laparotomies were performed because of PV or SMV thrombosis, which were initially reconstructed with tangential suturing and corrected with a patch reconstruction after thrombectomy. There were three post-operative haemorrhages that needed a re-laparotomy after surgery, none of which were related to venous reconstructions. One involved an early post-operative haemorrhage and two occurred more than 24 hours after surgery. One grade C haemorrhage underwent an angiogram, which showed no active bleeding. Two re-operations were performed due to DGE, one because of a grade C pancreatic fistula. Six re-operations resulted from infection complications: two in the transverse laparotomy wound, two superficial revisions in the vein harvesting site, and two exploratory laparotomies due to non-specific infection in the operative area. No statistical differences were observed in complications between venous reconstruction techniques (Table 4).

After spiral graft reconstruction, fewer days in total were spent in the ICU compared with end to end reconstruction ($p = .003$). No statistical differences were observed for in hospital stay days (Table 5).

Complications specific to pancreaticoduodenectomy were analysed separately. There were five (3%) clinically relevant post-pancreatectomy fistulas, 18 (11%) grade B/C DGE cases, and eight (5%) grade B bile leaks, with no grade

Table 5. Post operative re-admission to intensive care (ICU) and total hospital stay in 198 patients undergoing pancreatectomy and venous reconstruction between 2005 and 2018, divided by type of venous repair

	All (*n*=198)	Spiral graft (*n*=69)	End to end (*n*=77)	Tangential/Patch (*n*=52)	*p**
Re-admission to ICU					
Mean	1.34	1.57	1.16	1.31	
Median (IQR)	1.00 (0–2)	1.00 (0–2)	0 (0–1)	1.00 (0–1)	.003
Hospital stay – d					
Mean	12.22	13.16	12.05	11.21	
Median (IQR)	11.00 (5–72)	10 (5–72)	11 (6–29)	10 (5–28)	.77

ICU = intensive care unit; IQR = interquartile range.
* The Kruskal–Wallis test, *p* values for *post hoc* Mann–Whitney tests for re-admission to ICU were $p = .003$ between spiral graft *vs.* end to end, and $p = .079$ between spiral graft *vs.* tangential patch (Bonferroni correction for multiple testing used and $p < .025$ considered statistically significant here).

Table 6. Post-operative complications in 171 patients undergoing pancreaticoduodenectomy and venous resection/reconstruction between 2005 and 2018 in a single centre, divided by type of venous repair

Complication[†]	All (n = 171)	Spiral graft (n = 60; 35%)	End-to-end (n = 69; 40%)	Tangential/Patch (n = 42; 25%)	p value
PPH					.088
None	89 (52)	26 (43)	41 (59)	22 (52)	
Grade A	39 (23)	19 (32)	9 (13)	11 (26)	
Grade B	40 (23)	15 (25)	16 (23)	9 (21)	
Grade C	3 (2)	0	3 (4)	0	
PV/SMV thrombosis					.74
No	160 (94)	55 (92)	64 (93)	41 (93)	
Yes	5 (3)	2 (3)	3 (4)	0	
Other*	6 (4)	3(5)	2 (3)	1(2)	
Re-operations					.049
No	159 (93)	56 (93)	61 (88)	52 (100)	
Yes	12 (7)	4 (7)	8 (12)	0	
POPF					.33
None	147 (86)	56 (93)	56 (81)	35 (83)	
Grade A	19 (11)	4 (7)	9 (13)	6 (14)	
Grade B	4 (2)	0	3 (4)	1 (2)	
Grade C	1 (1)	0	1 (1)	0	
DGE					.36
None	139 (81)	50 (83)	58 (84)	31 (74)	
Grade A	14 (8)	2 (3)	5 (7)	7 (17)	
Grade B	13 (8)	6 (10)	4 (6)	3 (7)	
Grade C	5 (3)	2 (3)	2 (3)	1 (2)	
Bile leak					.28
None	162 (95)	55 (92)	65 (94)	42 (100)	
Grade A	1 (1)	1 (2)	0	0	
Grade B	8 (5)	4 (7)	4 (6)	0	
Grade C	0	0	0	0	
Chyle leak					.94
None	137 (85)	51 (86)	52 (83)	34 (87)	
Grade A	1 (2)	0	1 (2)	0	
Grade B	23 (14)	8 (14)	10 (16)	5 (13)	

Data are presented as n (%). PPH = postpancreatectomy haemorrhage; PV/SMV = portal vein/superior mesenteric vein; POPF = postoperative pancreatic fistula; DGE = delayed gastric emptying.

* Other refers to thrombosis of the aorta (n = 1), pulmonary embolism or deep vein thrombosis (n = 11).

[†] For explanations of Grades, please refer to Outcome analysis in the Methods section.

C complications observed. Complications after pancreaticoduodenectomy are summarised in Table 6.

Long term survival

Median follow up among reconstructed patients was two years, ranging from one month to a maximum of 13 years and five months. In the surveillance period, the disease progressed in 128 (65%) patients, and in 43 (22 %) patients there was local recurrence. Median time of progression of pancreatic adenocarcinoma was 277 days and the shortest time to diagnose a recurrence was 33 days. No statistically significant differences between venous reconstruction techniques and progression of disease were seen (p = .74).

Overall median survival (OS) among patients with pancreatic ductal adenocarcinoma (PDAC) undergoing pancreaticoduodenectomy between 2005 and 2018 was 2.11 years (95% confidence interval [CI] 1.83 — 2.40). Comparatively, among patients undergoing pancreaticoduodenectomy and a combined venous reconstruction (PDVR) the median OS was 2.24 years (95% CI 1.64 — 2.83; p = .40; Fig. 3A).

In a subsequent analysis, the data for the periods 2005 to 2011 *vs.* 2012 to 2018 were grouped. A significant increase in survival was detected after PDVR in the latter time period. Between 2005 and 2011, median OS after pancreaticoduodenectomy was 2.28 years (95% CI 1.88 — 2.68) compared with a median OS after PDVR of 1.72 years (95% CI 0.85 — 2.59; p = .036). More recently from 2012 to 2018, no difference between procedures was observed. Median OS after pancreaticoduodenectomy was 2.14 years (95% CI 1.73 — 2.54) increasing after PDVR to 2.76 years (95% CI 1.93 — 3.59; p = .14; Supplementary Fig. S1). No difference in survival after PDVR was observed between different reconstruction techniques, p = .351 (see survival curves in Fig. 3B).

Survival was also analysed comparing the resection margins and neo-adjuvant treatment in venous reconstruction patients. Patients undergoing a radical resection (R0) had a median OS of 2.74 years (95% CI 1.68 — 3.81), which after non-radical resection (R1) fell to 1.73 years (95% CI 1.04 — 2.41; p = .075). With or without neo-adjuvant treatment, the median OS was 2.74 years (95% CI 1.95 — 3.53; p = .41) *vs.* 1.91 years (95% CI 1.20 — 2.63; p = .37). Further analysis revealed no differences in survival based on different reconstruction techniques for patients with or without neo-adjuvant treatment or the radicality of the resection. The

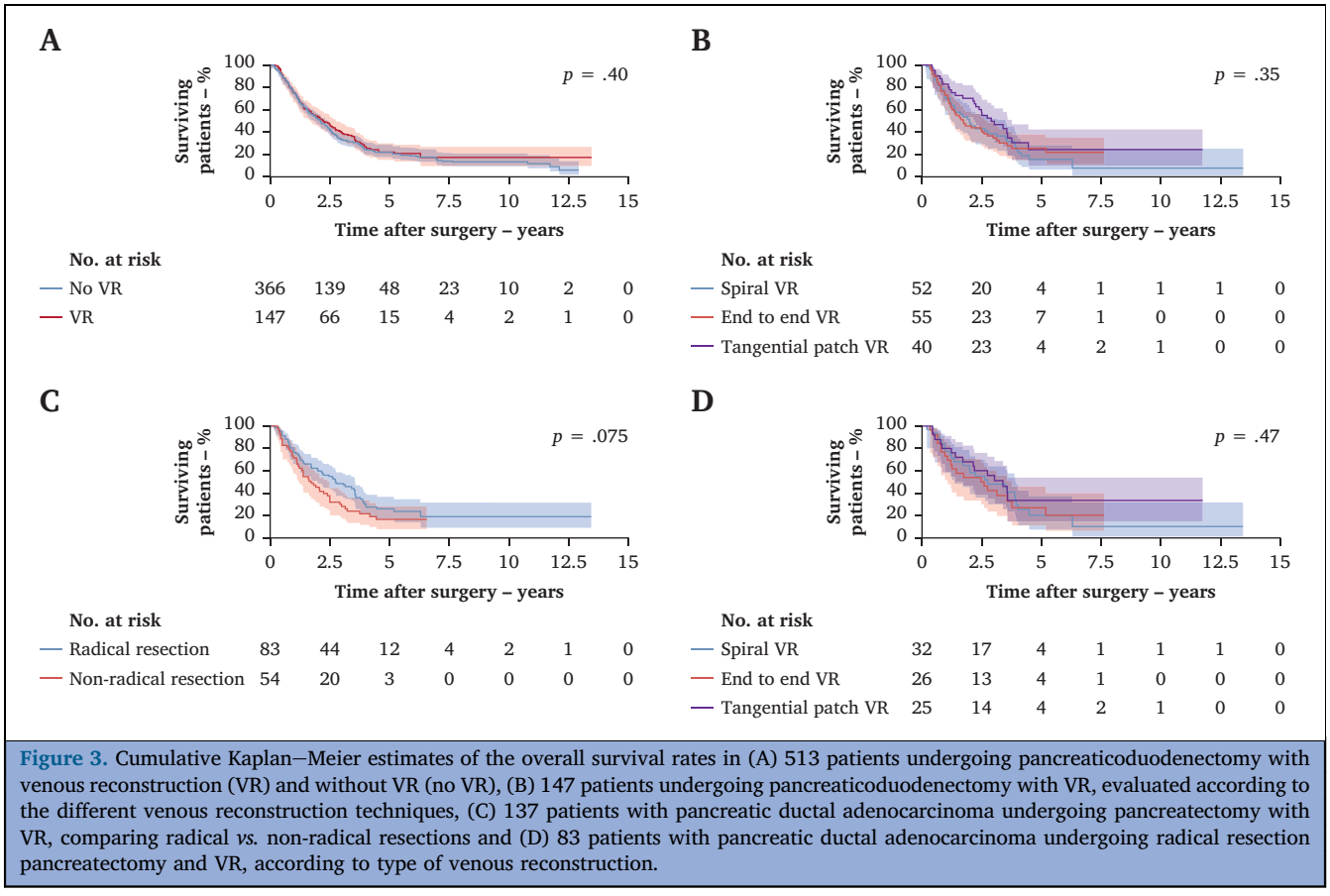

Figure 3. Cumulative Kaplan–Meier estimates of the overall survival rates in (A) 513 patients undergoing pancreaticoduodenectomy with venous reconstruction (VR) and without VR (no VR), (B) 147 patients undergoing pancreaticoduodenectomy with VR, evaluated according to the different venous reconstruction techniques, (C) 137 patients with pancreatic ductal adenocarcinoma undergoing pancreatectomy with VR, comparing radical *vs.* non-radical resections and (D) 83 patients with pancreatic ductal adenocarcinoma undergoing radical resection pancreatectomy and VR, according to type of venous reconstruction.

survival curves based on Kaplan–Meier analysis comparing R0 and R1 resections appear in Fig. 3C and D. Cox regression models on survival for patients with PDAC appear in Table 7.

DISCUSSION

In this study the aim was to determine if the preferred technique for longer venous resections, the autologous spiral graft reconstruction, was safe to use together with pancreatectomy in borderline resectable pancreatic tumours and whether there were significant differences between reconstruction techniques. Although pancreatic resection together with vascular resection and reconstruction has been validated in the past, the techniques for long reconstructions, in particular, vary. Several studies determined that long reconstructions are performed in patients with advanced disease and in difficult inflammatory conditions in the portomesenteric area, which could lead to increased post-operative complication rates and thrombotic events. Pancreatectomy specific complications are important to acknowledge, since the most problematic complication, pancreatic fistula, can lead to vascular and entero-anastomotic failure or haemorrhage from the gastroduodenal artery stump when the pancreatic fluid leaks to the operative area.

Several different autologous conduits for the portomesenteric reconstruction have been used. During the process of fine tuning the preferred conduit, the femoral veins and longitudinally sutured GSV pieces were tested, with the spiral graft found to be the better option. In this clinic, autologous femoral veins are used routinely and a local homograft bank of cryopreserved cadaveric arteries and veins for other indications such as aortic graft infections is maintained, although it is unsuitable for this practice.[22] The spiral graft does not spasm, kinks are easily controlled, and the size is adjustable. To accommodate a larger diameter and longer reconstructions, such as in reconstructing the inferior vena cava, prosthesis, pericardium, or cryopreserved cadaveric veins are used. One patient was seen with massive intestinal swelling after clamping of the portomesenteric veins, which resolved after reconstruction. After this, a shunting protocol was planned, but did not require further action. Shunting procedures may be more useful in emergency settings, where the liver must be isolated. The time from harvesting to the final anastomosis of the spiral graft is not much more than one hour, with portomesenteric clamp times of around 30 minutes, probably explaining why no shunting was needed in this series.

Co-operation between vascular and pancreatic surgeons is fluid in the hospital. Vascular surgeons are notified if vascular invasion is identified or suspected on pre-operative scanning and if potential resection and reconstruction is needed. Vascular surgeons pre-operatively assess the autograft possibilities and a joint decision regarding the reconstruction method is performed intra-operatively by the vascular and pancreatic surgeons. Unexpected vascular invasion remains rare, while pre-planned reconstructions that are ultimately unnecessary sometimes occur.

The aim of this study was to validate the clinical experience on choosing the reconstruction method. The largest

Table 7. Cox regression analysis on survival among patients with pancreatic ductal adenocarcinoma ($n = 146$) after pancreatectomy with venous resection and reconstruction

	Univariable		Multivariable	
	HR (95% CI)	*p*	HR (95% CI)	*p*
Study arm				
Spiral graft	1		1	
End-to-end	0.945 (0.611−1.462)	.80	1.112 (0.636−2.018)	.72
Tangential/Patch	0.706 (0.430−1.157)	.17	0.565 (0.280−1.051)	.083
Radicality				
R0/R1	0.716 (0.486−1.054	.090	1.524 (0.887−2.616)	.13
Neo-adjuvant				
Yes/No	0.761 (0.512−1.129	.17	0.988 (0.558−1.748)	.97
TNM staging				
T1	1		1	
T2	1.875 (0.746−4.715	.18	2.554 (0.943−6.917)	.066
T3	2.127 (0.793−5.705)	.13	3.381 (1.150−9.941)	.027
T4	1.747 (0.417−7.326	.45	1.545 (0.350−6.14	.57
N0	1		1	
N1	1.804 (0.982−3.316)	.057	1.562 (0.793−3.077)	.20
N2	3.303 (1.820−5.993)	<.001	3.227 (1.560-6.676)	.002

CI = confidence interval; HR = hazard ratio; TNM = classification of malignant tumour spread; T = tumour stage; N = lymph nodes; M = distant metastasis. Re-admission to ICU between spiral graft *vs.* tangential/patch, $p = .079$.

cohort from Johns Hopkins was presented by Glebova in 2014, which indicated no differences in portomesenteric reconstruction methods except for synthetic interposition grafts, for which more thrombotic events were observed. In their study, neither comorbidities nor tumour grade appeared to impact post-operative outcomes.[11] More thrombotic events in interposition grafts were suggested in the results from Dua and colleagues in 2015, who analysed data from a total of 90 patients, among whom 19 involved various interposition grafts (internal jugular, renal, saphenous, and superficial femoral vein; $p = .001$).[23] This agrees with the experience whereby spiral vein grafts do not spasm and the adjustable size is beneficial. Studies have shown that interposition grafts are safe, although the technique and autografts used vary greatly between studies.[5–7,11,24]

The focus is on the surgical technique and its safety compared with techniques that have been studied and published extensively. Fujii *et al.* in 2015 reported their retrospective cohort study, which indicated that resections > 3 cm would not be feasible with end to end reconstruction.[9] In this study, an interposition graft was indicated in similar long venous resections or if the end to end reconstruction evaluated was under too much tension. In the same study, the vascular graft patency rates were analysed using post-operative imaging and status updates.[9] Venous patency was studied when clinically indicated, specifically, computed tomography scans with contrast were included in the oncological follow up, which included 137 patients. These data suggested no partial or total stenosis of the reconstructed veins. Patients for whom data were missing were not included in the oncological follow up, possibly representing a major limitation to the findings. Snyder and colleagues surveyed patency rates after venous reconstruction with the internal jugular vein in 2017, and for a size mismatch the use of bovine pericardium tubes was considered justified. In their study, acute thrombosis occurred in 7.5% of cases, but differences between reconstruction techniques were not analysed.[7] A spiral graft represented a valid choice for a size mismatch during venous reconstructive surgery.

This is the largest study of GSV used as a spiral interposition graft. In order to increase the portomesenteric blood flow and potentially improve patency, the splenic vein was implanted into the side of the graft when it did not significantly prolong the operation or introduce kinking to the reconstruction. Previously, left sided portal hypertension and its severe outcomes rarely occurred following venous resection.[25] Tanaka and colleagues published a report in 2019, whereby a splenic vein resection led to signs of left sided portal hypertension (gastro-oesophageal varices or thrombocytopenia) if critical confluence veins were also resected, although severe complications such as bleeding or long term abdominal pain remained rare.[26]

The long term results were analysed with a separate analysis of the oncological results, surgical techniques, and surveying the importance of neo-adjuvant treatment. Neo-adjuvant treatment and a radical (R0) resection might give a survival benefit for patients; however, statistically significant differences in the data were not observed. The pathological accuracy of the R0 *vs.* R1 analysis has increased over the years and thus the results are not fully comparable. Neo-adjuvant treatment has become more efficient and all patients suspected of having a vascular invasion pre-operatively are evaluated for pre-operative oncological treatment. Wolfgang and colleagues in 2021 reported that neo-adjuvant treatment accompanying R1 resections would not reduce patient survival.[27] The radicality of the procedure was harder to evaluate than previously based on resection lines. Surgical treatment has evolved towards more standardised procedures and the oncological regimen has become more efficient, which might impact survival of PDVR patients, as described in Supplementary Fig. S1.

The strengths of the study lie in the uniform technique developed by a limited number of surgeons performing

such procedures and the large number of patients analysed. Some clear limitations remain. First, a retrospective study was carried out with the data spanning many years, which might result in some data being lost in older patient records. In addition, the operative technique might have changed over the study period. Reporting and recording pancreatic specific complications became more consistent following the consensus statements from the international study group concerning the classification of complications.

The aim was to analyse the safety of the GSV interposition graft, examining surgical or non-surgical complications occurring up to 90 days post-operatively. No differences in hospital stays or the number or severity of complications were detected compared with other types of venous resections or in patients not requiring a venous resection, even though spiral interpositions were performed when more advanced venous infiltration was observed. Only few thrombotic events occurred following interposition grafts, which were compared with end to end and tangential reconstruction, and no differences between the techniques were observed.

Conclusions

This retrospective study found that an interposition spiral graft using patients' autologous GSV appeared safe and feasible as an option when reconstructing PV/SMV together with pancreatic surgery. As in previous studies, it was confirmed that venous invasion, resection, and reconstruction do not worsen the prognosis of pancreatic cancer patients.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2022.04.006.

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COUP D'OEIL

Double Trouble! Concomitant Ipsilateral Symptomatic Popliteal Venous Aneurysm

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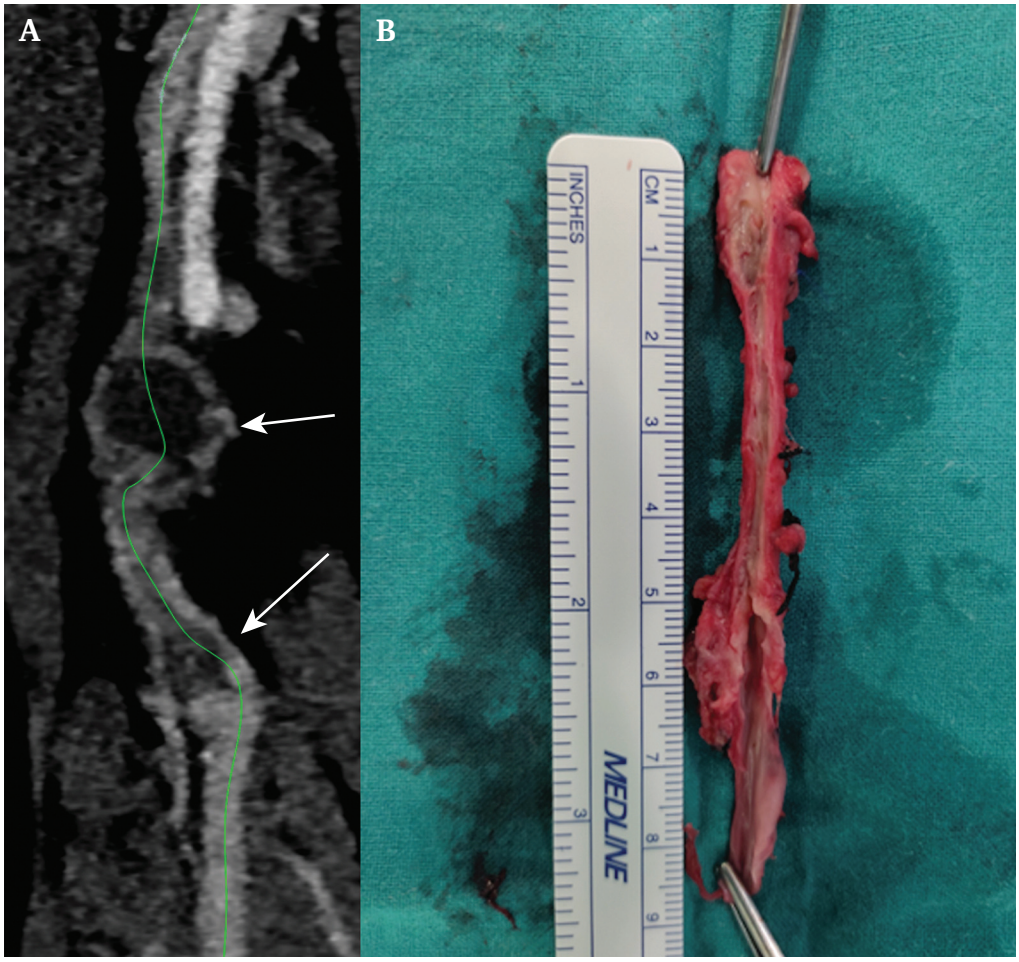

A 50 year old woman presented with calf oedema, pain, and paraesthesia of 48 hours duration. A duplex ultrasound scan showed a partially thrombosed popliteal venous aneurysm. Computed tomography angiography (CTA) revealed two isolated popliteal venous aneurysms (diameters of 28 and 16 mm, respectively) involving the same popliteal vein (A, arrows), with inner thrombus. CTA also identified a double system, with another non-thrombosed, non-aneurysmal popliteal vein. Resection of the venous segment, including both venous aneurysms, was performed (B). No reconstruction (e.g., venous bypass) was required because of the double venous system. The post-operative course was uneventful.

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