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Original Article

Venous wedge and segment resection during pancreatoduodenectomy for pancreatic cancer: impact on short- and long-term outcomes in a nationwide cohort analysis

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Abstract

Background: Venous resection of the superior mesenteric or portal vein is increasingly performed in pancreatic cancer surgery, whereas results of studies on short- and long-term outcomes are contradictory. The aim of this study was to evaluate the impact of the type of venous resection in pancreatoduodenectomy for pancreatic cancer on postoperative morbidity and overall survival.

Methods: This nationwide retrospective cohort study included all patients who underwent pancreatoduodenectomy for pancreatic cancer in 18 centres (2013–2017).

Results: A total of 1311 patients were included, of whom 17 per cent underwent wedge resection and 10 per cent segmental resection. Patients with segmental resection had higher rates of major morbidity (39 *versus* 20 *versus* 23 per cent, respectively; $P < 0.001$) and portal or superior mesenteric vein thrombosis (18 *versus* 5 *versus* 1 per cent, respectively; $P < 0.001$) and worse overall survival (median 12 *versus* 16 *versus* 20 months, respectively; $P < 0.001$), compared to patients with wedge resection and those without venous resection. Multivariable analysis showed patients with segmental resection, but not those who had wedge resection, had higher rates of major morbidity (odds ratio = 1.93, 95 per cent c.i. 1.20 to 3.11) and worse overall survival (hazard ratio = 1.40, 95 per cent c.i. 1.10 to 1.78), compared to patients without venous resection. Among patients who received neoadjuvant therapy, there was no difference in overall survival among patients with segmental and wedge resection and those without venous resection (median 32 *versus* 25 *versus* 33 months, respectively; $P = 0.470$), although there was a difference in major morbidity rates (52 *versus* 19 *versus* 21 per cent, respectively; $P = 0.012$).

Conclusion: In pancreatic surgery, the short- and long-term outcomes are worse in patients with venous segmental resection, compared to patients with wedge resection and those without venous resection.

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Introduction

Pancreatic cancer is one of the few types of cancer for which the survival rate has barely improved in the last decades[1]. Radical tumour resection preceded or followed by chemo(radio)therapy is the current standard treatment for patients with pancreatic cancer[2,3]. The International Study Group of Pancreatic Surgery (ISGPS) suggests that partial resection of the portal vein or superior mesenteric vein (PV-SMV) should be performed in case of their suspected involvement in order to achieve radical resection[4]. Use of venous resection during pancreatoduodenectomy is increasing and is expected to increase further with the use of neoadjuvant therapy[5–8].

An international survey reported that most pancreatic surgeons prefer venous segment resection with primary anastomosis over partial venous wedge resection, because of a lower perceived risk of complications[9]. Literature regarding complications after different types of venous resection is contradictory[8,10–12]. A recent meta-analysis of mostly single-centre observational studies showed that venous resection is associated with increased mortality and worse survival[13]. Data on the type of venous resection are not available. Nationwide studies with contemporary data representing current clinical practice are lacking.

The aim of this nationwide study was to evaluate the impact of venous resection type during pancreatoduodenectomy for pancreatic cancer on postoperative morbidity, mortality and overall survival.

Methods

Study design and patient selection

This nationwide retrospective cohort study included all 18 centres (18 patients) that are part of the multidisciplinary Dutch Pancreatic Cancer Group (DPCG)[14]. All patients registered in the mandatory prospective nationwide Dutch Pancreatic Cancer Audit (DPCA)[15] who underwent pancreatoduodenectomy for pancreatic adenocarcinoma (postoperative pathological diagnosis) from 2013 to 2017 were included. Due to the retrospective nature of the study, the Medical Ethics Committee of the Leiden University Medical Centre waived the need for obtaining informed consent (G18.103). This study was performed in accordance with the Declaration of Helsinki and is reported in accordance with the STROBE criteria[16].

Data collection

Data were requested from the DPCA, including baseline, intraoperative, postoperative, and histopathological characteristics. Additional data were manually extracted from patients' medical records (for example, type of venous resection, blood loss, duration of surgery, PV-SMV thrombosis, tumour invasion in resected vein, lymphangio invasion, perineural invasion, follow-up characteristics).

Definitions

The type of venous resection was scored according to ISGPS classification as follows: type 1, partial venous excision with direct suture closure (venorrhaphy); type 2, partial venous excision using a patch; type 3, venous segment resection with primary venovenous anastomosis; and type 4, venous segment resection with interposed venous conduit and at least two anastomoses[4]. For the present analysis, type 1 and 2 resections were categorized as 'wedge resection', and type 3 and 4 resections as 'segmental resection'.

Venous involvement on preoperative imaging was defined as absence or presence of a fat plane between the tumour and PV-SMV. Resectability was defined according to the DPCG criteria: resectable (tumour without arterial involvement and with venous involvement $<90°$); borderline resectable (tumour with arterial involvement $<90°$ and/or venous involvement 90–269° without occlusion); and locally advanced (tumour with arterial involvement $\geq 90°$ and/or venous involvement $\geq 270°$ or occlusion). Neoadjuvant preoperative therapy was categorized as no/yes, regardless of type, duration, and dose of chemo(radio)therapy. Neoadjuvant therapy was mainly administered according to the protocol of the PREOPANC trial[17] in which patients with resectable and borderline resectable disease were included (preoperative chemoradiotherapy, which consisted of three courses of gemcitabine, with the second course combined with 15×2.4 Gy radiotherapy) and occasionally outside this trial setting at the discretion of the treating physician. Additional organ resection was defined as any additional organ resection not including standard pancreatoduodenectomy[18]. Pancreatic surgery-specific complications were classified in accordance with ISGPS criteria. Only grade B and C complications were reported, as these complications were considered clinically relevant[19–24]. Postoperative PV-SMV thrombosis within 30 days following surgery was scored, based on imaging studies which were performed at the discretion of the attending physician. The Clavien–Dindo classification was used for scoring within 30 days following surgery, with grade $\geq$ III considered as major morbidity[25]. Postoperative mortality was defined as death within 90 days following surgery, unless the cause of death was clearly disease-related (for example, early recurrence or metastasis), and not surgery-related[26]. Textbook outcome was defined as absence of postoperative pancreatic fistula, bile leak, postpancreatectomy haemorrhage (all ISGPS grades B and C), major morbidity, readmission, and postoperative mortality[27]. The eighth edition of the TNM classification was used for histological classification[28]. An R1 resection margin was defined as the presence of tumour cells within 1 mm of the resection margin[29]. Due to inclusion of patients with neoadjuvant therapy, overall survival was calculated as time length in months between the start of treatment (day of surgery or start of neoadjuvant therapy) and the date of death (or last follow-up visit) and was truncated at 48 months.

Outcomes and comparisons

Primary outcomes of this study were major morbidity (Clavien–Dindo grade $\geq$ III) and overall survival (since start of treatment). Secondary outcomes were postoperative characteristics: postoperative mortality; PV-SMV thrombosis; postoperative pancreatic fistula; postpancreatectomy haemorrhage; bile leakage; delayed gastric emptying; chyle leak; pneumonia; wound infection; relaparotomy; radiological intervention; (duration of) intensive care unit admission; (duration of) hospital stay; readmission; textbook outcome and adjuvant therapy; and histopathological characteristics (resection margin status, tumour invasion in the resected vein, tumour size on pathology, pN-stage, pM-stage, tumour differentiation grade, lymphangio invasion, and perineural invasion).

Patients were analysed by category of venous resection: without venous resection, wedge and segmental resection. Subgroup analysis was performed on patients who received neoadjuvant therapy.

Table 1 Population characteristics by category of venous resection

		Without venous resection	Wedge resection	Segmental resection	P-value
Total		960 (73.2)	227 (17.3)	124 (9.5)	–
Sex	M	554 (57.7)	115 (50.7)	65 (52.4)	0.11
	F	406 (42.3)	112 (49.3)	59 (47.6)	
Age (years), median (i.q.r.)		68 (61–74)	68 (61–73)	69 (62–74)	0.73
BMI (kg/m^2), mean (s.d.)		25.1 (4.2)	24.5 (3.9)	23.8 (3.4)	0.002
ECOG	**0–1**	862 (89.8)	196 (86.3)	112 (90.3)	0.31
	2–4	98 (10.2)	31 (13.7)	12 (9.7)	
Preoperative biliary drainage		542 (56.5)	135 (59.5)	68 (54.8)	0.64
Venous involvement on preoperative imaging		252 (26.3	134 (59.0)	93 (75.0)	< 0.001
Preoperative resectability status*	Resectable	780 (83.3)	126 (56.8)	46 (38.3)	< 0.001
	Borderline resectable	113 (12.1)	76 (34.2)	62 (51.7)	
	Locally advanced	43 (4.6)	20 (9.0)	12 (10.0)	
Neoadjuvant therapy		57 (5.9)	21 (9.3)	23 (18.5)	< 0.001
Type of neoadjuvant therapy	Chemoradiotherapy	33 (57.9†)	12 (57.1†)	13 (56.5†)	0.99
	Chemotherapy	24 (42.1†)	9 (42.9†)	10 (43.5†)	
ASA score	I–II	742 (77.3)	176 (77.5)	97 (78.2)	0.97
	III–IV	218 (22.7)	51 (22.5)	27 (21.8)	
Minimally invasive procedure		109 (11.4)	10 (4.4)	4 (3.2)	< 0.001
Type of surgery	Classic Whipple	347 (36.1)	75 (33.0)	53 (42.7)	0.45
	PPPD	591 (61.6)	145 (63.9)	68 (54.8)	
	PRPD	22 (2.3)	7 (3.1)	3 (2.4)	
Texture of pancreatic remnant	Normal/soft	451 (47.0)	79 (34.8)	38 (30.6)	< 0.001
	Fibrotic/hard	509 (53.0)	148 (65.1)	86 (69.4)	
Pancreatic duct diameter (mm), median (i.q.r.)		5 (3–8)	6 (4–9)	6 (4–9)	< 0.001
Arterial resection		9 (0.9)	5 (2.2)	3 (2.4)	0.16
Additional resection		51 (5.3)	9 (4.0)	13 (10.5)	0.031
Duration of surgery (min), median (i.q.r.)		295 (239–377)	344 (278–423)	388 (321–458)	< 0.001
Blood loss during surgery (ml), median (i.q.r.)		600 (350–1000)	700 (450–1100)	1200 (600–2000)	< 0.001

*According to the Dutch Pancreatic Cancer Group criteria.†Percentage is based on the number of patients who received neoadjuvant therapy. Values are frequencies (per cent) unless indicated otherwise. Missing data imputed: BMI ($n = 8$); ECOG ($n = 6$); texture of pancreatic remnant ($n = 103$); pancreatic duct diameter ($n = 256$); duration of surgery ($n = 136$); blood loss ($n = 148$). Missing data not imputed: preoperative resectability status ($n = 33$). i.q.r., interquartile range; ECOG, Eastern Cooperative Oncology Group; PPPD, pylorus-preserving pancreatoduodenectomy; PRPD, pyloric ring pancreatoduodenectomy.

Statistical analysis

Statistical analyses were performed using SPSS Statistics for Windows, Version 23.0 (IBM, Armonk, New York, USA). Continuous variables are presented as the mean with s.d. or the median with interquartile range (i.q.r.), depending on the distribution. Categorical variables are presented as frequencies with percentages. Continuous variables were compared using the Mann–Whitney *U* test or Kruskal–Wallis test. Categorical variables were compared using the chi-square test or Fisher's exact test.

Missing data for multivariable analysis (BMI, Eastern Cooperative Oncology Group, aspect of the pancreatic remnant, diameter of the pancreatic duct, blood loss, duration of surgery, tumour size on pathology, pN-stage, tumour differentiation grade, lymphangio invasion, perineural invasion) were imputed 25 times based on relevant prognostic factors (venous resection, sex, age, biliary drainage, neoadjuvant therapy, ASA score, minimally invasive procedure, arterial resection, additional organ resection, resection margin status, pM-stage) and outcome variables (major morbidity and overall survival).

Log-transformation was performed for not normally distributed variables[30]. Multivariable binary logistic regression analysis was performed to assess the impact of the category of venous resection on major morbidity and to adjust for potential confounders. Overall survival was reported as the median with 95 per cent confidence intervals, and Kaplan–Meier curves and log rank tests were used to compare groups. A multivariable Cox proportional hazards model was used to assess the impact of the type of venous resection on overall survival and adjust for potential confounders. A sensitivity analysis was performed for the impact of category of venous resection on major morbidity and overall survival with complete cases, without multiple imputation, to show robustness of the results. A two-sided *P*-value < 0.050 was considered statistically significant.

Results

In total, 1311 patients who underwent pancreatoduodenectomy for pancreatic cancer were included, of whom 351 (27 per cent) underwent venous resection. Characteristics are shown in *Table 1*. Of the patients who had venous resection, 227 (65 per cent) underwent wedge resection (196 patients with type 1, 31 patients with type 2) and 124 (35 per cent) underwent segmental resection (97 patients with type 3, 27 patients with type 4). Several baseline characteristics differed significantly across the categories of venous resection (*Table 1*). Patients with segmental resection more often had venous involvement on preoperative imaging, compared to patients with wedge resection and those without venous resection (93 (75 per cent) *versus* 134 (59 per cent) *versus* 252 (26 per cent) patients, respectively; $P < 0.001$). Patients with segmental resection more often received neoadjuvant therapy, compared to patients with wedge resection and those without venous resection (23 (19 per cent) *versus* 21 (9 per cent) *versus* 57 (6 per cent) patients, respectively; $P = 0.012$).

Over the study period, the annual rate of venous resection increased from 20 to 32 per cent ($P = 0.001$; *Figure S1*). Variation was observed in the number of pancreatoduodenectomies (range 38–129), the percentage of venous resection (range 10–53 per cent), and the segmental-to-wedge resection ratio (range 0–6) per centre during the study period (*Figure S2*).

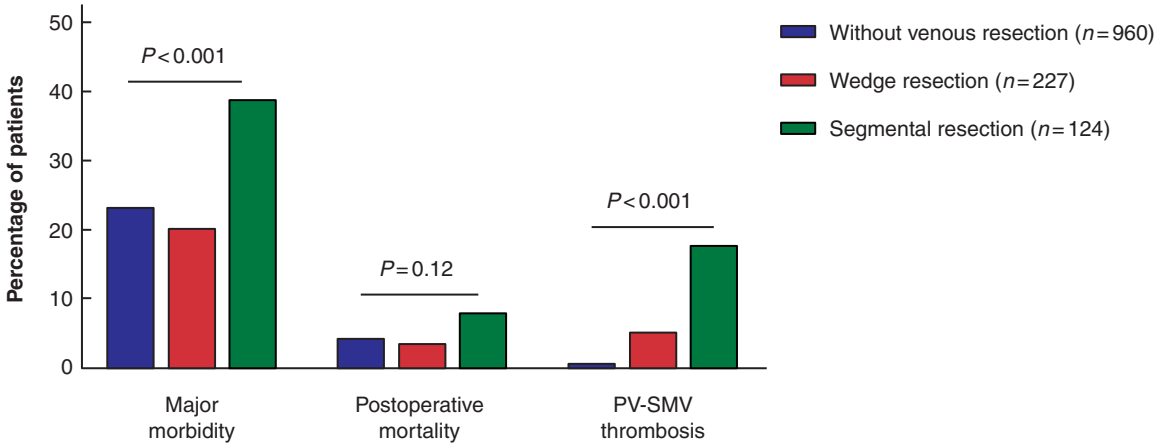


Fig. 1 Major morbidity (Clavien–Dindo grade ≥ III), postoperative mortality, and portal vein–superior mesenteric vein thrombosis after pancreatoduodenectomy for pancreatic cancer by category of venous resection

Table 2 Multivariable analysis of major morbidity (Clavien–Dindo grade ≥ III) and overall survival by category of venous resection

		Major morbidity			Overall survival		
		Odds ratio	95% c.i.	P-value	Hazard ratio	95% c.i.	P-value
Category of venous resection*	Wedge resection	0.95	0.64–1.40	0.79	1.04	0.86–1.27	0.68
	Segmental resection	1.93	1.20–3.11	0.007	1.40	1.10–1.78	0.007
Sex†	F	1.06	0.81–1.39	0.68	1.01	0.87–1.17	0.95
Age (years)‡		1.00	0.99–1.02	0.95	1.02	1.01–1.02	0.001
BMI (kg/m^2)‡		1.01	0.98–1.05	0.41	0.99	0.97–1.01	0.25
ECOG§	2–4	0.80	0.51–1.28	0.36	0.87	0.68–1.11	0.25
Preoperative biliary drainage*		0.90	0.69–1.18	0.44	–	–	–
Preoperative resectability status¶	Borderline resectable	0.89	0.62–1.28	0.54	–	–	–
	Locally advanced	0.46	0.23–0.91	0.024	–	–	–
Neoadjuvant therapy*		1.46	0.88–2.43	0.15	0.90	0.66–1.22	0.51
ASA score#	III–IV	1.68	1.23–2.31	0.001	1.45	1.22–1.73	< 0.001
Minimally invasive procedure*		1.49	0.94–2.36	0.09	–	–	–
Arterial resection*		1.59	0.55–4.55	0.39	–	–	–
Additional resection*		1.59	0.92–2.73	0.10	–	–	–
Texture pancreatic remnant**	Fibrotic/hard	0.79	0.60–1.05	0.11	–	–	–
Pancreatic duct diameter (mm)‡		0.94	0.90–0.98	0.005	–	–	–
Duration of surgery (min)‡		1.00	1.00–1.00	0.55	–	–	–
Blood loss (ml)‡		1.00	1.00–1.00	< 0.001	–	–	–
Resection margin status††	R1	–	–	–	1.26	1.08–1.48	0.004
Tumour size on pathology (mm)‡		–	–	–	1.01	1.00–1.02	0.008
pN-stage‡‡	N1	–	–	–	1.11	0.92–1.36	0.29
	N2	–	–	–	1.45	1.17–1.80	0.001
pM-stage§§	M1	–	–	–	1.22	0.79–1.89	0.36
Tumour differentiation grade¶¶	Moderate	–	–	–	1.55	1.17–2.04	0.002
	Poor/undifferentiated	–	–	–	2.26	1.69–3.02	< 0.001
Lymphangio invasion*		–	–	–	1.10	0.92–1.31	0.30
Perineural invasion*		–	–	–	1.21	0.94–1.36	0.29

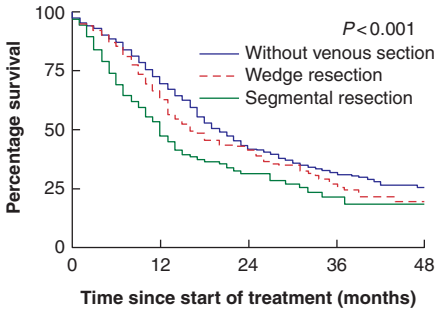
*Reference category: 'without/no'. †Reference category: 'male'. ‡Continuous variable. §Reference category: '0–1'. ¶Reference category: 'resectable'. #Reference category: 'I–II'. **Reference category: 'normal/soft'. ††Reference category: 'R0'. ‡‡Reference category: 'N0' §§Reference category: 'M0'. ¶¶Reference category: 'good'. ECOG, Eastern Cooperative Oncology Group.

Major morbidity

Patients with segmental resection had a higher rate of major morbidity, compared to patients with wedge resection and those without venous resection (*Fig. 1*). Results of multivariable analysis for major morbidity is shown in *Table 2*. Segmental resection was an independent predictor for major morbidity, whereas wedge resection was not. A sensitivity analysis with complete cases showed similar results (*Table S1*). Major morbidity rates were not different between patients with and those without venous involvement on preoperative imaging for wedge (30 (22 per cent) *versus* 16 (17 per cent) patients, respectively; $P = 0.34$) and segmental resection (13 (42 per cent) *versus* 35 (38 per cent) patients, respectively; $P = 0.67$).

Overall survival

Patients with segmental resection had worse overall survival (median 12 months, 95 per cent c.i. 9 to 15 months), compared to patients with wedge resection (median 16 months, 95 per cent c.i. 12 to 20 months) and without venous resection (median 20 months, 95 per cent c.i. 18 to 22 months; $P < 0.001$; *Fig. 2*). Results of multivariable analysis for overall survival is shown in *Table 2*. Segmental resection was an independent predictor for worse overall survival, whereas this could not be demonstrated for wedge resection (*Table 2*). A sensitivity analysis with complete cases showed similar results (segmental resection: hazard ratio (HR) 1.35, 95 per cent c.i. 1.02 to 1.77; wedge resection: HR 0.97, 95 per cent c.i. 0.77 to 1.23; *Table S1*). A post-hoc analysis, which also



No. at risk					
Without venous section (blue)	959	579	250	108	45
Wedge resection (red)	227	131	55	20	6
Segmental resection (green)	124	60	23	7	2

Fig. 2 Kaplan–Meier curves of overall survival after pancreatoduodenectomy for pancreatic cancer by category of venous resection

adjusted for use of adjuvant therapy in patients without postoperative mortality, showed similar results (segmental resection: HR 1.34, 95 per cent c.i. 1.04 to 1.72; wedge resection: HR 1.11, 95 per cent c.i. 0.91 to 1.36; *Table S2*).

Postoperative characteristics

Postoperative mortality did not differ significantly among patients with segmental resection, those with wedge resection, and those without venous resection (*Fig. 1*). Patients with segmental resection had a higher rate of PV-SMV thrombosis, compared to patients with wedge resection and those without venous resection (22 (18 per cent) *versus* 12 (5 per cent) *versus* 9 (1 per cent) patients, respectively; $P < 0.001$). Patients with segmental resection had a higher rate of relaparotomy, chyle leak, radiological intervention, intensive care unit admission and readmission, longer hospital stay, and a lower rate of textbook outcome, compared to patients with wedge resection and those without venous resection (*Table 3*). Vascular complications (PV-SMV thrombosis or haemorrhage) were the indication for relaparotomy in 18 out of 23 (78 per cent) patients with segmental resection (*Table S3*).

The rate of adjuvant therapy was lower in patients with segmental resection, compared to patients with wedge resection and those without venous resection (66 (58 per cent) *versus* 169 (78 per cent) *versus* 646 (71 per cent) patients, respectively; $P < 0.001$). Similar results regarding the rate of adjuvant therapy were obtained in the subgroup of patients without neoadjuvant chemotherapy and no postoperative mortality (51 (54 per cent) *versus*

Table 3 Postoperative and histopathological characteristics by category of venous resection

		Without venous resection	Wedge resection	Segmental resection	P-value
Postoperative characteristics					
Postoperative pancreatic fistula		87 (9.1)	11 (4.8)	7 (5.6)	0.07
Postpancreatectomy haemorrhage		72 (7.5)	9 (4.0)	12 (9.7)	0.09
Bile leakage		29 (3.0)	5 (2.2)	4 (3.2)	0.78
Delayed gastric emptying		160 (16.7)	31 (13.7)	25 (20.3)	0.26
	Missing	1	0	1	
Chyle leak		25 (2.6)	12 (5.3)	18 (14.5)	< 0.001
Pneumonia		58 (6.0)	10 (4.4)	9 (7.3)	0.51
Wound infection		100 (10.4)	19 (8.4)	11 (8.9)	0.60
Relaparotomy		69 (7.2)	13 (5.7)	23 (18.5)	< 0.001
Radiological intervention		135 (14.1)	21 (9.3)	23 (18.5)	0.041
ICU admission		92 (9.6)	23 (10.1)	27 (21.8)	< 0.001
Duration of ICU admission in days*, median (i.q.r.)		4 (2–12)	6 (3–13)	5 (2–13)	0.77
	Missing	5	2	1	
Duration of hospital stay in days†, median (i.q.r.)		11 (8–16)	10 (8–14)	15 (11–23)	< 0.001
	Missing	2	1	0	
Readmission†		134 (14.6)	32 (14.6)	35 (30.7)	< 0.001
Textbook outcome		638 (66.5)	159 (70.0)	60 (48.4)	< 0.001
Adjuvant therapy†		646 (71.2)	169 (77.5)	66 (58.4)	0.001
	Missing	12	1	1	
Histopathological characteristics					
Resection margin status	R0	519 (54.1)	80 (35.2)	44 (35.5)	< 0.001
	R1	441 (45.9)	147 (64.8)	80 (64.5)	
Tumour invasion in resected vein		–	69 (57.5)	58 (66.7)	0.18
	Missing		107	37	
Tumour size on pathology in mm, median (i.q.r.)		30 (22–38)	31 (25–40)	35 (27–41)	< 0.001
pT-stage	T1	135 (14.1)	19 (8.4)	11 (8.9)	< 0.001
	T2	590 (61.8)	141 (62.4)	62 (50.4)	
	T3	214 (22.4)	55 (24.3)	45 (36.6)	
	T4	16 (1.7)	11 (4.9)	5 (4.1)	
pN-stage	N0	255 (26.6)	59 (26.0)	34 (27.4)	0.97
	N1	381 (39.7)	86 (37.9)	49 (39.5)	
	N2	324 (33.8)	82 (36.1)	41 (33.1)	
pM-stage	M0	936 (97.5)	222 (97.8)	120 (96.8)	0.84
	M1	24 (2.5)	5 (2.2)	4 (3.2)	
Tumour differentiation grade	Good	135 (14.0)	27 (11.9)	14 (11.3)	0.78
	Moderate	543 (56.6)	123 (54.2)	70 (56.5)	
	Poor/undifferentiated	282 (29.4)	77 (33.9)	40 (32.3)	
Lymphangio invasion		518 (54.0)	144 (63.4)	73 (58.9)	0.49
Perineural invasion		792 (82.5)	208 (91.6)	104 (83.9)	0.95

*Patients admitted to the ICU. †Patients without postoperative mortality. Values are frequencies (per cent) unless indicated otherwise. Missing data imputed: pN-stage ($n = 1$); pT-stage and tumour size on pathology ($n = 7$); tumour differentiation grade ($n = 125$); lymphangio invasion ($n = 225$); perineural invasion ($n = 147$). ICU, intensive care unit; i.q.r., interquartile range.

149 (76 per cent) *versus* 607 (71 per cent) patients, respectively; $P < 0.001$).

Histopathological characteristics

Patients with segmental and wedge resection had a higher rate of R1 resections, compared to patients without venous resection (*Table 3*). Data on tumour invasion in the resected vein were available for 207 patients (59 per cent). Tumour invasion did not differ between patients with wedge resection and those with segmental resection. Patients with segmental resection had larger tumours, compared to patients with wedge resection and those without venous resection.

Patients who received neoadjuvant therapy

In total, 101 (8 per cent) patients received neoadjuvant therapy. Baseline characteristics and histopathological characteristics were largely comparable among the categories of venous resection (*Table S4*). Patients with segmental resection had higher rates of major morbidity, postoperative mortality, and PV-SMV thrombosis, compared to patients with wedge resection and those without venous resection. Multivariable analysis showed that segmental resection was an independent predictor for major morbidity, whereas this could not be demonstrated for wedge resection (*Table S5*).

There was no difference in overall survival among patients with segmental resection, those with wedge resection, and those without venous resection (*Figure S3*). Multivariable analysis showed both segmental and wedge resection did not predict overall survival (*Table S5*).

Discussion

This nationwide study of patients who underwent pancreatoduodenectomy for pancreatic cancer demonstrated that patients with venous segmental resection had a twofold increase in major morbidity rate and a 17 per cent increased risk of PV-SMV thrombosis, compared to patients without venous resection. The segmental resection group had worse overall survival, compared to patients with wedge resection and those without venous resection (median 12 *versus* 16 *versus* 20 months), even after correction for clinical and pathological factors. Among patients who received neoadjuvant therapy, overall survival showed no difference between patients with segmental resection, those who had wedge resection, and those without venous resection, whereas major morbidity and postoperative mortality rates were higher after venous segmental resection.

In contrast to the preference observed for segmental resection in the international survey, two-thirds of patients who had venous resection underwent wedge resection, with only one-third who had segmental resection. The reasons for choosing to perform venous resection and reconstruction type are multifactorial and based on the surgeon's preference and skills, as well as on the perceived circumference and length of vein involvement[31]. Little is known about what exactly drives the surgeon's preference with regard to choice of type of venous reconstruction[9].

Large studies focusing on outcome and type of venous resection are sparse. The largest study (977 venous resections) used the National Surgical Quality Improvement Program (NSQIP) database and showed that, compared to no venous resection, direct repair (72 per cent) was associated with higher morbidity and graft repair (28 per cent) was associated with higher morbidity and mortality[8]. Unfortunately, comparison with the present study is difficult since the study did not use the ISGPS venous resection definition and Clavien–Dindo classification. Another large study (229 venous resections) showed no difference in morbidity, mortality, and survival among the types of venous resection[11]. In contrast to a single-centre study of 249 patients (period 2000–2010)[32], patients with and those without venous involvement on preoperative imaging and venous resection had comparable major morbidity rates. Based on the available data, it can only be speculated what the exact reasons were for the higher major morbidity rates after segmental resection. Previously, vascular complications were shown to be the main causes of postoperative mortality[33] and were the main indication for relaparotomy in these patients. There are no studies available investigating the association between outcome and the number or proportion of venous resections performed at an institution. This was not investigated here since only patients who underwent pancreatoduodenectomy for pancreatic cancer were included and there was no clear association between the volume of pancreatoduodenectomies and the proportion of venous resection or category of venous resection. Future research should focus on identifying optimal venous reconstruction techniques and protocols (for example, clamping time, length of vein resected, type of conduit, preservation or ligation of the splenic vein, heparinization, etc.).

The rate of PV-SMV thrombosis after segmental resection (18 per cent) was higher, compared to other studies (approximately 8 per cent)[11,34,35]. The present study had no patient-level data on thromboprophylaxis to study the effect on PV-SMV thrombosis. However, it was reported that only 29 per cent of Dutch surgeons adjusted thromboprophylaxis following venous resection (some start a platelet aggregation inhibitor or increase the dose of low-molecular-weight heparin)[9]. A previous meta-analysis found no differences in PV-SMV thrombosis in patients with and those without thromboprophylaxis[34]. Moreover, intensified thromboprophylaxis might result in more haemorrhages[36], reflecting the fragile balance between thromboprophylaxis, postoperative thrombosis, and haemorrhage in pancreatic surgery.

Segmental resection, but not wedge resection, was a predictor for worse overall survival in this study. This is most likely explained by the fact that patients who require segmental resection have more advanced disease, despite the fact that multivariable analysis adjusted for several patient and histopathological characteristics. The question of whether wedge, rather than segmental, resection produces improved outcome in otherwise identical patients is a topic for further research.

Tumour invasion in the resected vein was observed in 61 per cent of patients with venous resection, which is within the range reported in the literature (32–82 per cent)[37]. It is difficult for a surgeon to distinguish a tumour from peritumoural inflammation and fibrosis on a scale of millimetres. Several studies have shown varying results regarding the significance of circumference and length of vein involvement on preoperative imaging[38,39]. The added value of intraoperative ultrasound for this assessment is being investigated within the DPCG. A previous study showed that radical venous resection can rarely be achieved due to the microanatomy at the venous margin and the broadly invasive growth pattern of pancreatic cancer[40]. More research is needed to identify patients who would truly benefit from venous resection, so that patients are not put at unnecessary risk of surgical complications.

In this cohort, only 8 per cent of patients received neoadjuvant therapy. This is comparable with recently published results from Germany (5 per cent) and Sweden (3 per cent), though lower than results from the United States (28 per cent)[41]. This is probably

due to the fact that neoadjuvant therapy was mainly administered in a trial setting during the study period in most European countries (including the Netherlands). The comparable overall survival across the categories of venous resection after neoadjuvant therapy may be explained by the effect of neoadjuvant therapy, as well as by patient selection, as patients with advanced, aggressive, or therapy-resistant tumours are no longer considered good candidates for resection. Patients who received neoadjuvant therapy with segmental resection had a very high rate of major morbidity and postoperative mortality. There is little evidence on outcomes of venous resection after neoadjuvant therapy. A previous study showed major morbidity in 7 out of 15 (47 per cent) patients who underwent venous resection after neoadjuvant therapy for locally advanced pancreatic cancer. It should be noted that these resections were performed in a high-volume centre[42].

This study has several limitations. First, because this was a retrospective study, collecting and interpreting data from medical records have the risk of information and classification bias. However, a previous study by the DPCA showed that data registration is complete, with high accuracy[15]. Multiple imputations were used to solve the problem of missing data. Sensitivity analysis with complete cases showed similar outcomes, indicating robustness of the results. Second, given the observational design of this study, confounding by indication should be considered as the surgeon's decision (for example, selection for neoadjuvant therapy and venous resection) was made in the clinical and surgical context of the patient. Although multivariable analysis adjusted for potential confounders, inherent differences among the categories of venous resection may partly explain the observed results and residual confounding cannot be ruled out. Furthermore, no definitive conclusions can be drawn regarding neoadjuvant therapy since the sample size was relatively small and details of neoadjuvant therapy (type, cycles, doses, fractions, etc.) were not available for analysis. Lastly, there were missing data in the pathology reports on tumour invasion in the resected vein (41 per cent). Unclear or absent marking of the specimen and pathology request forms can make it difficult for pathologists to recognize the resected vein, especially in the case of wedge resection[43]. Within the DPCG, several initiatives have been set up to standardize pathology requests and reports. The strengths of the present study are, unlike previous studies, its nationwide design, including all Dutch centres performing pancreatic surgery, and the resulting large cohort of patients spanning a relatively short study period (2013–2017).

Data availability

Data sets used in this study are available upon reasonable request from the corresponding author after completion of the MULTI-VERS PROJECT (www.trialregister.nl – TC 7644).

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Supplementary material

Supplementary material is available at *BJS* online.

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European Colorectal Congress

28 November – 1 December 2022, St.Gallen, Switzerland

Monday, 28 November 2022

09.50
Opening and welcome
Jochen Lange, St.Gallen, CH

10.00
It is leaking! Approaches to salvaging an anastomosis
Willem Bemelman, Amsterdam, NL

10.30
Predictive and diagnostic markers of anastomotic leak
Andre D'Hoore, Leuven, BE

11.00
SATELLITE SYMPOSIUM
ETHICON

11.45
Of microbes and men – the unspoken story of anastomotic leakage
James Kinross, London, UK

12.15
LUNCH

13.45
Operative techniques to reduce anastomotic recurrence in Crohn's disease
Laura Hancock, Manchester, UK

14.15
Innovative approaches in the treatment of complex Crohn Diseases perianal fistula
Christianne Buskens, Amsterdam, NL

14.45
To divert or not to divert in Crohn surgery – technical aspects and patient factors
Pär Myrelid, Linköping, SE

15.15
COFFEE BREAK

15.45
Appendiceal neoplasia – when to opt for a minimal approach, when and how to go for a maximal treatment
Tom Cecil, Basingstoke, Hampshire, UK

16.15
SATELLITE SYMPOSIUM
Medtronic
Further,Together

17.00
Outcomes of modern induction therapies and Wait and Watch strategies, Hope or Hype
Antonino Spinelli, Milano, IT

17.30
EAES Presidential Lecture - Use of ICG in colorectal surgery: beyond bowel perfusion
Salvador Morales-Conde, Sevilla, ES

18.00
Get-Together with your colleagues
Industrial Exhibition

Tuesday, 29 November 2022

9.00
CONSULTANT'S CORNER
Michel Adamina, Winterthur, CH

10.30
COFFEE BREAK

11.00
SATELLITE SYMPOSIUM
INTUITIVE

11.45
Trends in colorectal oncology and clinical insights for the near future
Rob Glynne-Jones, London, UK

12.15
LUNCH

13.45
VIDEO SESSION

14.15
SATELLITE SYMPOSIUM
BD

15.00
COFFEE BREAK

15.30
The unsolved issue of TME: open, robotic, transanal, or laparoscopic – shining light on evidence and practice
Des Winter, Dublin, IE
Jim Khan, London, UK
Brendan Moran, Basingstoke, UK

16.30
SATELLITE SYMPOSIUM
Takeda

17.15
Lars Pahlman lecture
Søren Laurberg, Aarhus, DK

Thursday, 1 December 2022
Masterclass in Colorectal Surgery
Proctology Day

Wednesday, 30 November 2022

9.00
Advanced risk stratification in colorectal cancer – choosing wisely surgery and adjuvant therapy
Philip Quirke, Leeds, UK

09.30
Predictors for Postoperative Complications and Mortality
Ronan O'Connell, Dublin, IE

10.00
Segmental colectomy versus extended colectomy for complex cancer
Quentin Denost, Bordeaux, FR

10.30
COFFEE BREAK

11.00
Incidental cancer in polyp - completion surgery or endoscopy treatment alone?
Laura Beyer-Berjot, Marseille, FR

11.30
SATELLITE SYMPOSIUM

12.00
Less is more – pushing the boundaries of full-thickness rectal resection
Xavier Serra-Aracil, Barcelona, ES

12.30
LUNCH

14.00
Management of intestinal neuroendocrine neoplasia
Frédéric Ris, Geneva, CH

14.30
Poster Presentation & Best Poster Award
Michel Adamina, Winterthur, CH

15.00
SATELLITE SYMPOSIUM
OLYMPUS

15.45
COFFEE BREAK

16.15
Reoperative pelvic floor surgery – dealing with perineal hernia, reoperations, and complex reconstructions
Guillaume Meurette, Nantes, FR

16.45
Salvage strategies for rectal neoplasia
Roel Hompes, Amsterdam, NL

17.15
Beyond TME – technique and results of pelvic exenteration and sacrectomy
Paris Tekkis, London, UK

19.30
FESTIVE EVENING

Information & Registration **www.colorectalsurgery.eu**