Original Article

Comparison of laparoscopic versus open pancreaticoduodenectomy combined with portal vein/superior mesenteric vein resection and reconstruction for pancreatic cancer: a propensity score matching analysis

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Background: Open surgery is gradually replaced by minimally invasive surgery, but few studies have reported the feasibility of laparoscopic pancreaticoduodenectomy (LPD) combined with vascular resection and reconstruction. The present study compared the efficacy of LPD with open pancreaticoduodenectomy (OPD) combined with portal vein/superior mesenteric vein (PV/SMV) resection and reconstruction for pancreatic cancer.

Methods: The clinical data of patients who underwent PD combined with PV/SMV resection and reconstruction from March 2016 to August 2022 at our institution were retrospectively analyzed. The perioperative outcomes and survival outcomes were compared after propensity score matching (PSM).

Results: The original cohort included 64 patients. Sixteen pairs of patients were obtained by 1:1 PSM. The intraoperative blood loss was greater in the OPD group than in the LPD group (550 *vs.* 200 mL, P=0.04), and the PV clamp time was longer in the LPD group than in the OPD group (29.4 *vs.* 18.8 min, P<0.001). There was no significant difference in the incidence of postoperative complications. The median overall survival and progression-free survival were comparable between the two groups (P>0.05).

Conclusions: LPD combined with PV/SMV resection and reconstruction is safe and feasible in selected patients and results in similar perioperative outcomes and prognosis as open surgery.

Keywords: Laparoscopy; pancreaticoduodenectomy (PD); pancreatic cancer (PC); propensity score matching (PSM)

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Introduction

Pancreaticoduodenectomy (PD) is the only regimen that may cure right-sided pancreatic cancer (PC), but when diagnosed, only approximately 20% of patients meet the criteria for resectable PC, up to 25% of PC patients are defined as locally advanced due to surrounding vascular involvement, and the remaining approximately 50% of PC patients already have distant metastasis (1). In the past, tumors involving the portal vein/superior mesenteric vein (PV/SMV) or the PV/SMV confluence have been classified as locally advanced and considered contraindications for surgery. In 2006, the MD Anderson Cancer Center recommended tumor invasion of the PV/SMV was one of the definitions of borderline resectable PC (BRPC), and this criterion was included in the National Comprehensive Cancer Network (NCCN) guidelines in the same year (2). In a 2009 expert consensus, Evans *et al.* (3) proposed that PD with venous resection as a standard treatment when the PV/SMV is locally invaded by a tumor. Several studies have since demonstrated that PD combined with venous resection has a similar postoperative complication and long-term prognosis compared to standard PD (4,5).

Minimally invasive surgery has become the trend in surgery. Laparoscopic techniques, with the advantages of small incisions and rapid recovery, have been widely used in clinical surgery. Gagner *et al.* (6) reported the first case of laparoscopic PD (LPD) in 1994, and some randomized controlled trials have demonstrated the laparoscopic advantages in perioperative outcomes of PD (7,8). The da Vinci Robotic Surgical System provides a three-dimensional surgical view, reduced hand tremor, and comfortable ergonomics (9,10). The first robotic PD (RPD) was performed in 2003 by Giulianotti *et al.* (11). LPD or RPD has gradually replaced open PD (OPD), but due to the difficulty of vascular reconstruction, there are few reports on LPD or RPD combined with venous resection. In addition, fewer studies have considered the impact of different venous reconstruction modalities on outcomes. There is a controversy as to whether different reconstruction modalities have an impact on postoperative complications and long-term prognosis (12,13). In the present study, we intend to compare the perioperative outcome and oncological prognosis of OPD and LPD combined with vascular resection and reconstruction by propensity score matching (PSM) and to investigate the feasibility, safety, and long-term efficacy of LPD combined with venous resection and reconstruction. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-23-538/rc).

Highlight box

Key findings

- The laparoscopic pancreaticoduodenectomy (LPD) group had the advantage of less bleeding, similar postoperative complication, and its long-term outcome was similar to that of the open pancreaticoduodenectomy (OPD) group.

What is known and what is new?

- Pancreaticoduodenectomy (PD) combined with venous resection has a similar postoperative complication and long-term prognosis compared to standard PD.
- Few studies have reported on the feasibility of LPD combined with portal vein/superior mesenteric vein (PV/SMV) resection and reconstruction. The perioperative outcomes and survival outcomes were compared after propensity score matching.

What is the implication, and what should change now?

- LPD combined with PV/SMV resection and reconstruction is safe and feasible in selected patients. This procedure should be considered for adoption by high-volume pancreatic centers.

Methods

Data collection

We retrospectively analyzed the medical records of patients who underwent PD combined with PV/SMV resection and reconstruction at The Affiliated Lihuili Hospital of Ningbo University from March 2016 to August 2022. They were categorized into laparoscopic and open groups according to surgical methods: 19 patients in the LPD group (LPD combined with venous resection and reconstruction) and 45 patients in the OPD group (OPD combined with venous resection and reconstruction). Criteria for inclusion: (I) postoperative pathological confirmation of pancreatic ductal adenocarcinoma (PDAC); and (II) intraoperative finding of tumor infiltration into the PV/SMV, with PV/SMV resection and reconstruction; exclusion criteria: (I) combined arterial resection and reconstruction; (II) incomplete clinical data; (III) patients lost to visit; (IV) total PD; (V) distant metastasis (*Figure 1*). The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This research was approved by the Ethics Committee of The Affiliated Lihuili Hospital of Ningbo University (approval number: Y2023YJZ128) and individual consent for this retrospective analysis was waived.

Variables and definitions

The basic patient data extracted from the electronic medical record system included age, sex, body mass index (BMI), carcinoembryonic antigen (CEA), serum carbohydrate antigen 19-9 (CA19-9), total bilirubin (TBIL), and preoperative biliary drainage. Perioperative indicators

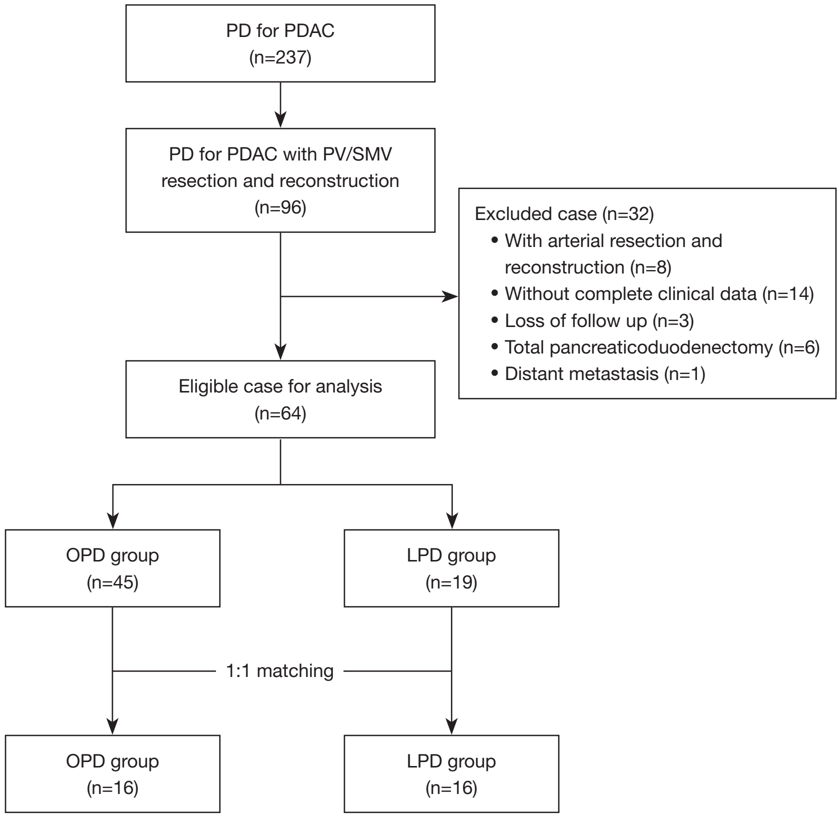


Figure 1 Flowchart of patient selection. PD, pancreaticoduodenectomy; PDAC, pancreatic ductal adenocarcinoma; PV/SMV, portal vein/superior mesenteric vein; OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy.

included operation time, intraoperative blood loss, intraoperative blood transfusion, vascular reconstruction method, PV clamp time, anastomotic patency, reoperation, and postoperative length of stay. The PV/SMV anastomotic patency rate was the definition of the anastomotic diameter divided by the diameter of the 1-cm blood vessel above the anastomosis on abdominal contrast-enhanced computed tomography (CECT) at 1 month after the surgery. The criteria for postoperative pancreatic fistula (POPF), delayed gastric emptying (DGE) and post-pancreatectomy hemorrhage (PPH) were according to the International Study Group of Pancreatic Surgery (ISGPS) criteria (14-16). Postoperative complications were graded according to the Clavien-Dindo classification (17), and grade ≥ III was defined as a serious complication. The pathological results included tumor diameter, tumor node metastasis (TNM) stage, nerve invasion, and resection margin. The TNM staging was based on the American Joint Committee on Cancer (AJCC) 8th staging system Edition (18). Absence of tumor cells on the resection margin was defined as R0 resection. Other indicators included neoadjuvant or adjuvant therapy, overall survival (OS) and progression-free survival (PFS). OS was defined as the time from the date of surgery to death or the last outpatient follow-up. Recurrence was considered to be a local recurrence or distant metastasis in any imaging examination. For follow-up, (I) within 3 years, blood tumor markers and hepatobiliary and pancreatic ultrasound were reevaluated every 3 months, and chest computed tomography (CT) and abdominal CECT scans were performed every 6 months; (II) beyond 3 years, blood tumor markers were reevaluated and chest CT and abdominal CECT scans were performed every 6 months.

Operative procedures

After anesthesia, the patient was placed in the supine position. An incision was made in the skin below the umbilicus and a pneumoperitoneum needle was placed to create a CO_2 pneumoperitoneum. A 10-mm trocar

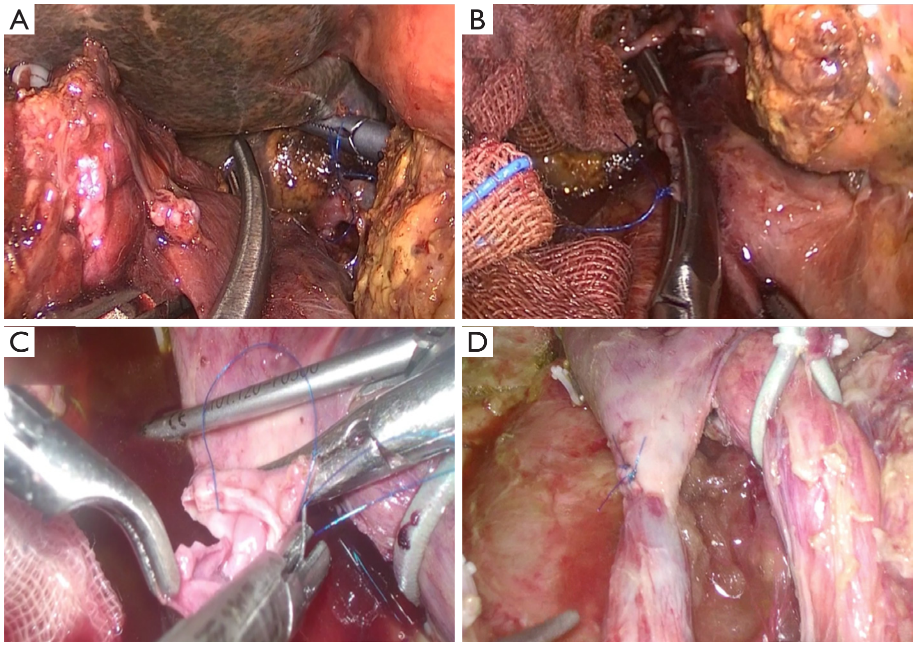
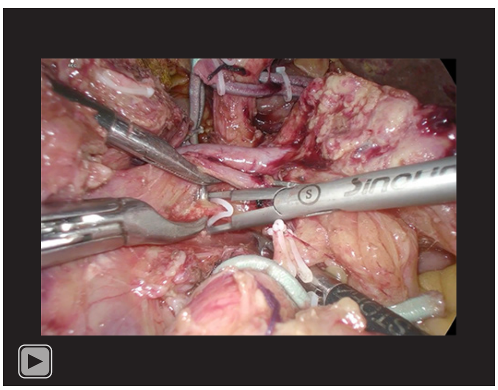


Figure 2 Vascular resection and reconstruction. (A) The lateral wall of the portal vein was clamped with vascular clips. (B) Portal vein after primary suture. (C) Anastomosis of segmental resected portal vein. (D) Portal vein after end-to-end anastomosis.



Video 1 Intraoperative video of laparoscopic pancreaticoduodenectomy combined with portal vein resection reconstruction. Reconstruction of the invaded portal vein with end-to-end anastomosis.

was placed under the umbilicus. Two 12-mm and two 5-mm trocars were placed on each side of abdomen. The gastrocolic ligament and hepatogastric ligament were divided, and the neck of the pancreas was exposed. The inferior vena cava, left renal vein, and abdominal aorta were exposed by the Kocher maneuver. The inferior border of the pancreas was dissected to expose the SMV and superior mesenteric artery. The distal stomach was dissected with an endoscopic stapler. Along the superior border of the pancreas, the common hepatic artery, gastroduodenal artery, and right gastric artery were dissected out, the lymph nodes were cleared. The gastroduodenal artery and the right gastric artery were ligated. Then the gallbladder was isolated and the common hepatic duct was clipped. The neck of the pancreas was dissected. The Treitz ligament was severed, and the jejunum was severed 10 cm away from the duodenojejunal flexure. Vascular reconstruction was performed according to the venous invasion type and site of vein invasion: tangential resection with primary suture was used for tumor invasion of the PV/SMV $<1/3$ of the vessel circumference. The lateral wall of the portal vein was clamped with vascular clips (*Figure 2A*), the tumor and the involved vein were excised, and continuous suture with 4-0 or 5-0 Prolene thread (*Figure 2B*). Segmental resection with primary end-to-end reconstruction for patients with tumor invasion of the PV/SMV $\geq 1/3$ of the vessel circumference. The portal vein and superior mesenteric vein were clamped with vascular clamps, the specimen was completely excised and continuous suture with 5-0 or 6-0 Prolene thread (*Figure 2C,2D*), as shown in *Video 1*. The technique of vascular reconstruction has been described previously (19). Reconstruction of the digestive tract using duct-to-mucosa pancreaticojejunostomy, gastrojejunostomy and

Table 1 Baseline characteristics before and after propensity score matching

Characteristic	Original cohort			Matched cohort		
	OPD (N=45)	LPD (N=19)	P	OPD (N=16)	LPD (N=16)	P
Age, years	65.8±9.6	65.8±11.0	0.99	67.2±9.1	67.2±9.5	>0.99
Sex			0.53			>0.99
Male	27 (60.0)	13 (68.4)		10 (62.5)	10 (62.5)	
Female	18 (40.0)	6 (31.6)		6 (37.5)	6 (37.5)	
BMI, kg/m^2	23.1±2.8	21.8±2.5	0.08	23.6±2.8	21.8±2.7	0.06
CEA, μg/L	2.2 (1.2–3.6)	2.4 (1.7–4.7)	0.26	2 (1.2–2.8)	2.9 (1.8–5.2)	0.20
CA19-9, IU/L	186.5 (31.8–662.9)	113.7 (16.8–1,186.4)	0.55	172.2 (90.3–505.4)	147.4 (15.9–1,499.6)	>0.99
TBIL, μmol/L	22.6 (10.1–137.2)	101.4 (13.5–192.5)	0.20	108.2 (9.2–199.7)	64.9 (12.4–175.4)	0.81
Preoperative biliary drainage	6 (13.3)	3 (15.8)	>0.99	2 (12.5)	2 (12.5)	>0.99
Neoadjuvant therapy	8 (17.8)	1 (5.3)	0.36	0	1 (6.3)	>0.99
Tumor size, cm	3.8±1.1	3.4±1.0	0.24	4.2±1.2	3.5±1.1	0.09
Type of vessel resection/reconstruction			0.02			0.47
Tangential resection + suture	10 (22.2)	10 (52.6)		5 (31.3)	8 (50.0)	
Segmental resection + suture	35 (77.8)	9 (47.4)		11 (68.7)	8 (50.0)	

Data are presented as mean ± standard deviation or median (interquartile range) or n (%). OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy; BMI, body mass index; CEA, carcinoembryonic antigen; CA19-9, carbohydrate antigen 19-9; TBIL, total bilirubin.

hepaticojejunostomy.

Statistical analysis

The data were processed using IBM SPSS Statistics (version 26.0, IBM Corp., Armonk, NY, USA). To reduce selection bias and nonrandomization, 1:1 PSM (caliper, 0.2) was performed for the following indicators included in the logistic regression model: age, sex, BMI, tumor diameter, CA19-9, CEA, TBIL, and vascular reconstruction method. Normally distributed continuous variables were expressed as the mean ± standard deviation (SD) and were analyzed using Student's *t*-test. Continuous variables that were not normally distributed were expressed as the median and interquartile range (IQR) and were analyzed using the Mann-Whitney *U* test. Categorical variables were expressed as numbers and percentages and were analyzed using the Chi-squared test or Fisher's exact test. Survival data were analyzed using the Kaplan-Meier method, and intergroup comparisons were performed using the log-rank test. R Statistics Software (version 4.3.2., R Core Team, R Project for Statistical Computing, Vienna, Austria) was used to plot OS and PFS curves. All P values were based on 2-sided statistical analyses, and intergroup differences were considered statistically significant when P<0.05.

Results

Demographic data

A total of 237 cases of PDAC underwent PD and 96 combined with vein resection and reconstruction from March 2015 to August 2022 in our center, 64 cases were finally included after filtering by exclusion criteria. Among 64 patients, including 45 in the OPD group and 19 in the LPD group. Segmental resection was mainly used in the OPD group, and tangential resection was mainly used in the LPD group. No significant difference in postoperative patency rates between the two reconstruction modalities (P=0.64). Significant differences in reconstruction modalities between the two groups in the original cohort. After PSM, 16 patient pairs were successfully matched. *Table 1* shows the baseline characteristics for the 16 patient

Table 2 Operative characteristics after propensity score matching

Characteristic	Original cohort			Matched cohort		
	OPD (N=45)	LPD (N=19)	P	OPD (N=16)	LPD (N=16)	P
Operative time, minutes	470.3±117.7	444.1±90.7	0.39	482.1±140.9	442.3±97.7	0.36
Estimated blood loss, mL	400 [200–900]	200 [200–400]	0.02	550 [212.5–1,325]	200 [200–450]	0.04
Blood transfusion	26 (57.8)	6 (31.6)	0.06	9 (56.3)	5 (31.3)	0.29
PV clamp time, minutes	19.4±5.6	28.7±8.7	<0.001	18.8±5.2	29.4±8.6	<0.001
Patency of the reconstructed vessels, %	77.1 [62.2–97.6]	72.5 [60.7–84.8]	0.56	79.6 [66.9–89.3]	70.8 [61.1–84.3]	0.45

Data are presented as mean ± standard deviation or n (%) or median [interquartile range]. OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy; PV, portal vein.

pairs. There was no significant difference in the baseline information between the two groups (P>0.05).

Surgical characteristics

Table 2 shows the surgical characteristics in the two groups. The LPD group was associated with less intraoperative bleeding and longer PV clamping time, regardless of pre- or post-PSM. After PSM, the LPD group had less intraoperative blood loss than the OPD group (200 *vs.* 550 mL, P=0.04), and a longer PV clamp time (29.4 *vs.* 18.8 min, P<0.001).

Postoperative complications and pathological features

As shown in *Table 3*, in the original cohort, only the incidence of DGE was significantly less in the LPD group than in the OPD group (5.3% *vs.* 37.8%, P=0.008). There were no significant differences in other postoperative complications and pathologic outcomes between the two groups.

After matching, there were three cases of POPF (both biochemical leak) in the OPD group, and they resolved after conservative treatment. There were five cases of POPF in the LPD group (three cases of biochemical leak, one case of grade B, and one case of grade C). The patient with grade B POPF was successfully discharged from the hospital after conservative treatment with medication and prolonged extubation. The patient with grade C POPF was ineffective after conservative treatment with persistent abdominal infections and underwent surgical exploration with combined anastomotic leak, which was cured and successfully discharged from the hospital after the reoperation. All six cases of DGE in the OPD group and one cases of DGE in the LPD group were relieved by prolonged gastric tube removal and conservative treatment with medications. There were four cases of PPH in the OPD group and three cases of PPH in the LPD group, all of which resolved after conservative treatment with fluid replacement and blood transfusion. There were no statistical differences in POPF, DGE, PPH, serious complications, reoperation, and postoperative length of stay between the two groups. R0 resection rate, TNM stage, nerve invasion, and adjuvant therapy did not significantly differ between the groups.

OS and PFS

Outpatient follow-up combined with telephone inquiry was used until May 1, 2023. The median follow-up time was 28 months. Before matching, the median OS of the OPD group was 16 months, and the median OS of the LPD group was 20 months (P=0.15) (*Figure 3A*). Although the different reconstruction modalities had no effect on the R0 resection rate (P=0.06), the OPD group recurred in a shorter period of time. The median PFS of the OPD group was 11 months, but the median PFS of the LPD group was not reached (P=0.03) (*Figure 3B*).

After matching, the median OS of the OPD group was 14 months, and the median OS of the LPD group was 20 months (P=0.53) (*Figure 4A*). The median PFS of the OPD group was 11 months, but the median PFS of the LPD group was not reached (P=0.33) (*Figure 4B*). The differences in OS and PFS between the two groups were not statistically significant.

Discussion

The procedure and feasibility of LPD with major vascular

Table 3 Postoperative outcomes after propensity score matching

Characteristic	Original cohort			Matched cohort		
	OPD (N=45)	LPD (N=19)	P	OPD (N=16)	LPD (N=16)	P
POPF	11 (24.5)	7 (36.8)	0.58	3 (18.8)	5 (31.3)	0.57
BL	8 (17.8)	5 (26.3)		3 (18.8)	3 (18.8)	
Grade B/C	3 (6.7)	2 (10.5)		0	2 (12.5)	
DGE	17 (37.8)	1 (5.3)	0.008	6 (37.5)	1 (6.3)	0.08
PPH	9 (20.0)	3 (15.8)	0.97	4 (25)	3 (18.8)	>0.99
Clavien-Dindo grade ≥3	6 (13.3)	1 (5.3)	0.61	1 (6.3)	1 (6.3)	>0.99
Reoperation	1 (2.2)	1 (5.3)	>0.99	0	1 (6.3)	>0.99
Postoperative length of stay, days	18 [13–25.5]	16 [12–19]	0.15	15.5 [12–20.8]	16 [12.3–19.8]	0.85
R0 resection	33 (73.3)	17 (89.5)	0.27	13 (81.3)	14 (87.5)	>0.99
T stage			0.59			0.27
T1	4 (8.9)	2 (10.5)		1 (6.3)	2 (12.5)	
T2	26 (57.8)	13 (68.4)		6 (37.5)	10 (62.5)	
T3	15 (33.3)	4 (21.1)		9 (56.3)	4 (25)	
N stage			0.68			0.15
N0	25 (55.6)	9 (47.4)		11 (68.8)	7 (43.8)	
N1	16 (35.6)	7 (36.8)		5 (31.3)	6 (37.5)	
N2	4 (8.9)	3 (15.8)		0	3 (18.8)	
AJCC TNM stage			0.54			0.10
I	16 (35.6)	8 (42.1)		4 (25.0)	6 (37.5)	
II	25 (55.6)	8 (42.1)		12 (75.0)	7 (43.8)	
III	4 (8.9)	3 (15.8)		0	3 (18.8)	
Nerve invasion	42 (93.3)	17 (89.5)	0.99	14 (87.5)	14 (87.5)	>0.99
Adjuvant chemotherapy	31 (68.9)	12 (63.2)	0.66	10 (62.5)	9 (56.3)	0.72

Data are presented as n (%) or median [interquartile range]. OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy; POPF, postoperative pancreatic fistula; BL, biochemical leak; DGE, delayed gastric emptying; PPH, post-pancreatectomy hemorrhage; AJCC, American Joint Committee on Cancer; TNM, tumor node metastasis.

resection has been described in previously published studies at our center (19). This study used 1:1 PSM to control confounding factors, such as the vascular reconstruction method and clinical baseline data, the results indicated the advantages of less intraoperative bleeding in the LPD group, with postoperative complications and long-term prognosis similar to that of the OPD group.

Due to the special anatomical location of the pancreas, PC often invades or adheres to the PV or SMV, which was previously considered a contraindication to surgery. With advancements in surgical technology and instruments, recent findings show that when PD combined with vascular resection is performed on patients with vein involvement, postoperative complications, mortality, and OS are similar to those for standard PD, and the prognosis is significantly different from that of patients who receive palliative care (20). ISGPS has recommends that patients with PC who have suspected PV/SMV involvement should have a concomitant venous resection to achieve an R0 margin, and standardized four modalities for portal vein

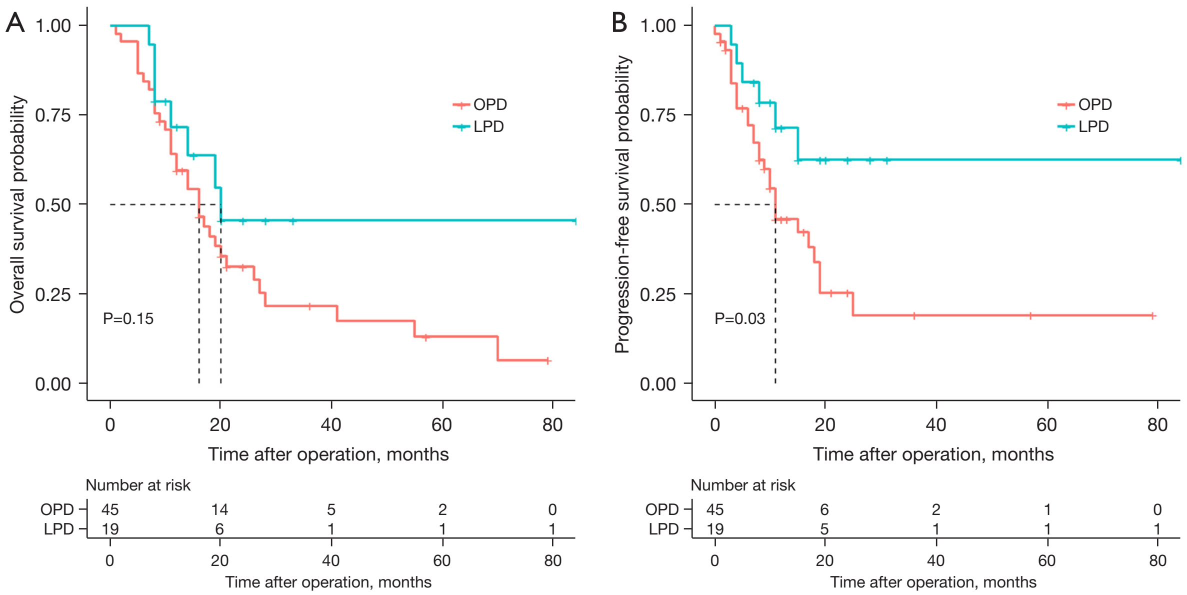


Figure 3 Comparison of overall survival and progression-free survival between the OPD and LPD groups before matching. (A) Overall survival before matching. (B) Progression-free survival before matching. OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy.

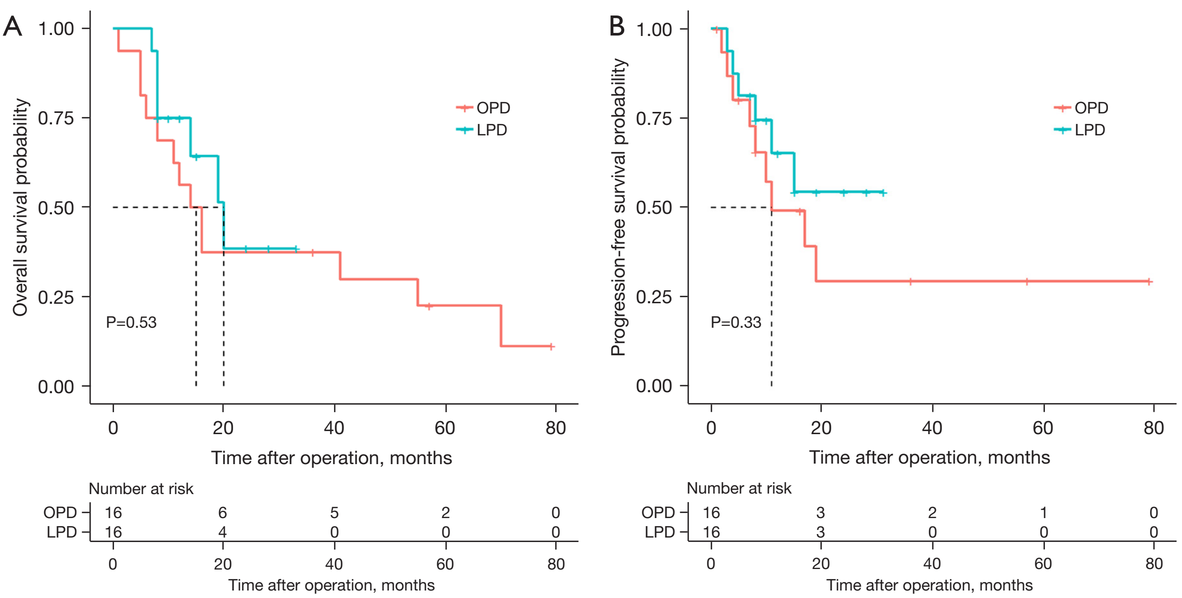


Figure 4 Comparison of overall survival and progression-free survival between the OPD and LPD groups after matching. (A) Overall survival after matching. (B) Progression-free survival after matching. OPD, open pancreaticoduodenectomy; LPD, laparoscopic pancreaticoduodenectomy.

reconstruction (1). The effect of the different venous reconstruction methods on perioperative outcomes and oncologic prognosis remains unclear. Ouyang *et al.* (21) retrospectively analyzed 142 patients showed that those with interposition graft had more frequent postoperative complications and worse prognosis compared to primary closure and end-end anastomosis, with no significant difference between the other two modalities. Another study showed poorer short- and long-term outcomes for segmental resection compared to wedge resection and those without venous resection (13). Conversely, in a descriptive study of different types of PV resection and reconstruction for BRPC, postoperative complication rates and in-hospital mortality of patients with different types of venous resection and reconstruction were similar, and the OS was significantly different among groups, i.e., with primary closure OS of 18.8 months, end-to-end anastomosis 27.6 months and interposition graft 13.3 months (P=0.022) (22), but the difference between the groups disappeared after multivariable analysis. Two methods for vascular resection and reconstruction were used in our institution. Segmental resection (10 cases of tangential resection and 35 cases of segmental resection) was mainly used in the OPD group, and tangential resection (10 cases of tangential resection and nine cases of segmental resection) was mainly used in the LPD group; there was a significant difference in the vascular reconstruction methods between the two groups (P=0.02), which disappeared after PSM.

In recent years, several institutions have reported minimally invasive surgery with major venous resection (19,23,24). Kendrick *et al.* (25) first reported LPD combined with vascular resection and reconstruction, proved the feasibility of the technique, and proposed that with the help of a good field of view, magnification and positive intra-abdominal pressure, it might give outcomes superior to those of open surgery. Subsequently, Croome *et al.* (26) showed that postoperative complications and mortality in the LPD group were not significantly different from those in the OPD group, with less blood loss, shorter postoperative hospitalization, and faster postoperative recovery. In this study, intraoperative blood loss was lower in the matched LPD group (200 *vs.* 550 mL; P=0.04). The result has been confirmed for standard LPD (27,28). Conversely, in a recent study, Sung *et al.* (29) reported more intraoperative bleeding in the LPD group than in the OPD group (897.6±606.1 *vs.* 460.4±421.2 mL; P=0.002), and that cooperation between surgeons was more difficult in laparoscopic than in open surgery, making it difficult to respond quickly to acute unanticipated bleeding, but no significant difference was found after balancing baseline levels by PSM (816.9±514.1 *vs.* 382.6±349.2 mL; P=0.068). However, the sample size of the LPD group in the study by Sung *et al.* was small and may only represent the early surgical practice of the center without reflecting the real world. In our study there was low intraoperative bleed loss in both groups; however, transfusion was frequent. This may be partly due to our aggressive transfusion management as well as the presence of anaemia in the patients preoperatively. The PV clamp time in the LPD group in this study was significantly longer than that in the OPD group (29.4 *vs.* 18.8 min, P<0.001), a finding that is similar to the results of previous studies by Croome and Sung *et al.* (26,29). Excessive duration of portal vein clamp can lead to intestinal congestion and edema, and no intestinal-related complications due to prolonged clamp were reported in either of these studies, including the present study. The anastomotic stenosis of the PV system is related to the mismatch in the diameter of the severed end of the vein due to excessive vein resection during the operation as well as high anastomotic tension. When the diameter of the anastomosis is <30% of the original diameter, it is considered severe anastomotic stenosis, and clinical symptoms often occur (30). The anastomotic diameters of 79.6% and 70.8% of the original diameter of the anastomosis in the OPD and LPD groups after matching, respectively, did not meet the definition of severe stenosis used in previous studies (30,31).

The results of this study showed that the postoperative complications and serious complications in the LPD group and the OPD group were similar. Except for a lower incidence of DGE in the LPD group (5.3% *vs.* 37.8%; P=0.008) in origin cohort, although there was no significant difference in the matched cohort, there was a trend of higher incidence of DGE in the OPD group than in the LPD group. Similar results were also found in the comparison of standard OPD and LPD (32,33). At present, the relationship between the lower incidence of DGE and LPD is still unclear. Some studies have suggested the following possible reasons for the low incidence of DGE in laparoscopic surgery: (I) association with performing PD without pylorus preservation and the method of gastrojejunal anastomosis (34); and (II) intraoperative preservation of the hepatic branch of the vagus nerve (35). Ding *et al.* (28) found a decreased incidence of postoperative DGE following LPD compared to OPD, although there was no statistically significant difference, in their study. They suggested that this was related to the reduced postoperative oedema after gastrointestinal reconstruction by laparoscopic surgery. In this study, due to the different surgical methods, the extent of hepatogastric ligament dissection was significantly smaller in the LPD group than in the OPD group. In addition, the LPD group did not have a large upper abdominal incision, and the postoperative adhesion of intra-abdominal organs to the abdominal wall was probably less in the LPD group, which may have resulted in an increased risk of postoperative DGE in the OPD group than in the LPD group.

The original purpose of PV/SMV resection and reconstruction is to completely remove the tumor to obtain negative resection margins and a better survival prognosis (36). PD combined with venous resection and reconstruction can obtain R0 resection rates similar to those of standard PD, which has been widely reported (4,37,38). Similar R0 resection rates can be achieved with laparoscopic surgery, i.e., previously reported R0 resection rates range from 69.2% to 96% (26,29,39). The R0 resection rates was 73.3% *vs.* 89.5% between OPD and LD, respectively, in the pre-match comparison (P=0.27) and 81.3% *vs.* 87.5% in the post-match comparison (P>0.99), which may partly explain the shorter PFS in original OPD group. In this study, there was a tendency for OS in the OPD group to be lower than that in the LPD group, but there was no significant difference. Although there was no significant difference in tumor diameter between the two groups after PSM, the tumor diameter in the OPD group tended to be larger than that in the LPD group. With the increase in tumor diameter, the difficulty of the surgical procedure also increases, which may partly explain the shorter OS and lower R0 resection rate in the OPD group.

Minimally invasive PD is difficult and has a long learning curve, and should be performed in experienced centers. A randomized controlled study in recent years has shown that LPD is associated with a higher mortality rate even in centers that perform 20 or more pancreaticoduodenectomies per year (40). The steep learning curve for LPD has caused surgeons to reconsider the safety of the procedure. Further randomized controlled studies should be conducted by more experienced surgeons. A recent unfinished multicenter randomized controlled study preliminarily reported similar short-term outcomes of LPD compared to open surgery (41). Although surgeons performing LPD in our center have accumulated a wealth of experience in LPD surgery, minimally invasive surgery is often selected in patients with low BMI in order to minimize the difficulty of LPD combined with vascular resection.

There are several limitations to this study. We only collected the 30-day postoperative patency rate, which is not enough to observe portal hypertension due to anastomotic stenosis (42). And this was a single-center retrospective study with small sample size and potential selection bias, and the LPD group did not reach the median PFS due to the short follow-up time, which still needs to be verified by prospective randomized controlled studies.

Conclusions

LPD combined with PV/SMV resection and reconstruction is feasible in PC and may achieve similar perioperative outcomes and survival benefit to open surgery. Further randomized controlled trials are still needed in the future.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://gs.amegroups.com/article/view/10.21037/gs-23-538/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-23-538/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This research was approved by the Ethics Committee of The Affiliated Lihuili Hospital of Ningbo University (approval number: Y2023YJZ128) and individual consent for this retrospective analysis was waived.

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