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ORIGINAL ARTICLE

Radical antegrade modular pancreatosplenectomy (RAMPS) versus conventional distal pancreatectomy for left-sided pancreatic cancer: findings of a multicenter, retrospective, propensity score matching study

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Abstract

Purpose Radical antegrade modular pancreatosplenectomy (RAMPS) has been reported to achieve high rates of a negative margin and resected metastatic lymph nodes. However, many studies have used historical controls and the results remain controversial. We conducted this study to compare the surgical and long-term outcomes of RAMPS vs. conventional distal pancreatectomy (DP).

Methods The subjects of this multicenter retrospective study were 106 patients who underwent curative resection for left-sided pancreatic cancer between 2012 and 2017. Overall survival (OS) and recurrence-free survival (RFS) rates were compared using Kaplan–Meier estimates.

Results The RAMPS group had more advanced T (T3/T4) and N stages (N1/N2) and a larger tumor size than the conventional group (T stage, $p=0.04$; N stage, $p=0.02$; tumor size, $p=0.04$). The RAMPS group had more harvested metastatic lymph nodes ($p=0.02$). After propensity-score matching, 37 patients from each group were included in the final analysis. There was no significant difference in RFS ($p=0.463$) or OS ($p=0.383$) between the groups. Multivariate analyses revealed the completion of chemotherapy to be an independent factor for RFS and OS (both $p<0.001$).

Conclusions There was no difference in the RFS or OS between RAMPS and conventional DP in this series. RAMPS may be an option for R0 resection of advanced tumors; however, postoperative chemotherapy has a greater influence than the surgical procedure on the prognosis of patients with pancreatic cancer.

Keywords Radical antegrade modular pancreatosplenectomy (RAMPS) · Conventional distal pancreatectomy · Left side pancreatic cancer · Body and tail pancreatic cancer

Introduction

Pancreatic body and tail cancers are aggressive, invading locally and metastasizing through the lymph nodes [1–3]. In 2003, Strasberg described a new distal pancreatectomy (DP) technique, termed "radical antegrade modular pancreatosplenectomy" (RAMPS), which is oncologically safe with respect to the dissection planes used to achieve negative margins as well as the extent of lymph node dissection, thereby improving patient outcomes [4–6]. In RAMPS, the posterior plane of dissection continues left from medial, exposing the left renal vein and clearing Gerota's fascia off the left kidney, or the dissection continues posteriorly to the diaphragm using the retroperitoneal muscles as the posterior border [4]. The rationale for this approach is to ensure a negative deep

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margin with complete regional lymph node dissection. The benefits of RAMPS for the resection of pancreatic cancer are well documented. Some studies have shown that RAMPS is associated with high negative tangential margin rates, more harvested lymph nodes, and better survival rates for pancreatic cancer [7, 8]. Although many studies have been reported, they used historical controls and the results remain controversial. This multicenter retrospective study compares the surgical outcomes and long-term prognosis of patients who underwent RAMPS with those who underwent conventional DP, based on propensity score matching.

Methods

Patients

The subjects were 106 consecutive patients who underwent curative surgical resection (R0/R1) for body and tail pancreatic cancer at Gangnam Severance Hospital ($n=40$) or Seoul St Mary's Hospital ($n=66$) between 2012 and 2017. None of these patients received neoadjuvant treatment. The study protocol was approved by the Institutional Review Board at Gangnam Severance Hospital, Yonsei University of Korea (3-2019-0175) and complied with the Declaration of Helsinki. Informed consent was obtained from all participants. Major complications were defined as Clavien–Dindo classification grade III and IV surgical complications [9]. Postoperative pancreatic fistulas were scored using the International Study Group on Pancreatic Fistula definition [10]. The definition of completion of postoperative chemotherapy was the completion of planned chemotherapy or six cycles. Both institutions are high-volume centers that perform 10 or more pancreatic cancer surgeries a year. The criteria for selecting RAMPS or conventional DP in both institutions were decided by the surgeon's protocols. Generally, conventional DP was selected when tumor was confined to the pancreas parenchyme or to the pancreas tail. In our protocol, abdominal computed tomography (CT) and blood tests, including tumor marker testing, were performed every 3 months for the duration of adjuvant therapy. After adjuvant therapy, tumor marker levels were checked every 3 months and abdominal CT was performed every 6 months or when the tumor marker levels were elevated.

Procedures

Conventional DP was performed as follows: A midline incision was made and the lesser sac was accessed through the gastrocolic ligament to expose the distal anterior pancreas. First, the pancreas neck was elevated from the confluence of the superior mesenteric vein (SMV), portal vein (PV), and splenic vein and then transected using GIA™ Staplers. The dissection continued more laterally from right to left. The area of lymph node dissection was only around the celiac trunk.

RAMPS was performed according to the procedure introduced by Strasberg and Fields. A midline incision was made and the pancreas neck was elevated from the PV and SMV. The pancreas neck was transected and the resection margin was repaired in the same manner as that in conventional DP. The range of medial-to-lateral lymph node dissection was upward to the diaphragmatic crus, downward to the left renal vein, and to the left lateral part of the aorta on the posterior side. The dissection continued more laterally from right to left on Gerota's fascia and divided the inferior mesenteric vein. In each case, the surgeon decided the type of RAMPS, whether anterior or posterior, based on which approach would optimize the chance of obtaining a negative tangential margin according to the principles described by Strasberg et al. A closed suction drain was placed in the pancreas stump and the abdomen was closed in layers [3].

Statistical analysis

All statistical analyses were performed using SPSS software, version 23.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were evaluated using the chi-square or Fisher's exact tests. Statistical analysis using propensity-score matching was performed by accounting for the covariates that predicted patient prognosis. A 1:1 match was performed according to two related covariates, namely T and N stages, to generate propensity scores. Overall survival (OS) and recurrence-free survival (RFS) curves were plotted using the Kaplan–Meier method and intergroup differences in survival time were assessed with the log-rank test. RFS was defined as the interval between the date of surgery and the date of recurrence or last follow-up. The Cox proportional hazards regression method was used to calculate independent prognostic factors. A p value of <0.05 was considered significant.

Results

Clinical characteristics of the patients with pancreatic cancer

Table 1 shows the clinicopathologic features of the 106 patients who underwent curative resection for left-side pancreatic cancer (RAMPS group, $n=53$; conventional group, $n=53$). The RAMPS procedure in this study consisted of anterior RAMPS ($n=15$) and posterior RAMPS ($n=38$). There were significant differences in sex, T stage, N stage, tumor stage, tumor size, and metastatic lymph nodes between the groups. The RAMPS group had more aggressive

Table 1 Clinical characteristics of the 106 patients with pancreatic cancer

	RAMPS ($n=53$)	Conventional DP ($n=53$)	p value
	Mean ± SD or N (%)		
Age	66.32 ± 8.97	64.96 ± 10.39	0.47
Sex			
Male	19 (35.8%)	29 (54.7%)	0.05
Female	34 (64.2%)	24 (45.3%)	
T stage, 8th			
T1	6 (11.3%)	12 (22.6%)	0.04
T2	22 (41.5%)	28 (52.8%)	
T3	22 (41.5%)	13 (24.5%)	
T4	3 (5.7%)	0 (0%)	
N stage, 8th			
N0	22 (41.5%)	31 (58.5%)	0.02
N1	16 (30.2%)	18 (34%)	
N2	15 (28.3%)	4 (7.5%)	
Stage, 8th			
IA	3 (5.7%)	12 (22.6%)	0.005
IB	10 (18.9%)	14 (26.4%)	
IIA	8 (15.1%)	5 (9.4%)	
IIB	15 (28.3%)	18 (34%)	
III	17 (32.1%)	4 (7.5%)	
Tumor size			
cm	4.24 ± 1.94	3.44 ± 2.11	0.04
Harvested Lymph node	15.81 ± 10.256	13.36 ± 9.831	0.21
Metastatic Lymph node	2.08 ± 2.663	1.08 ± 1.90	0.02
Perineural invasion			
Positive	42 (51.9%)	39 (73.6%)	0.41
Negative	10 (41.7%)	14 (26.4%)	
Unknown	1 (100%)	0 (0%)	
Lymphovascular invasion			
Positive	26 (49.1%)	17 (32.1%)	0.07
Negative	27 (50.9%)	36 (67.9%)	
Differentiation			
Well-Mod	47 (88.7%)	46 (86.8%)	> 0.99
Poorly-Undiff	5 (9.4%)	5 (9.4%)	
Unknown	1 (1.9%)	2 (3.8%)	
POPF			
No + Grade A	46 (86.8%)	50 (94.3%)	0.18
Grade B + C (clinically relevant POPF)	7 (13.2%)	3 (5.7%)	
Clavien dindo classification			
No	45 (84.9%)	50 (94.3%)	0.14
I–II	4 (7.5%)	0 (0%)	
III–IV	4 (7.5%)	3 (5.7%)	
Length of hospital stay			
Days	13.85 ± 6.359	14.66 ± 13.515	0.69
SMV-PV resection			
Yes	4 (7.5%)	2 (3.8%)	0.40
No	49 (92.5%)	51 (96.2%)	
Other organ resection			
Yes	10 (18.9%)	6 (31.6%)	0.33
No	43 (81.1%)	13 (68.4%)	

Table 1 (continued)

	RAMPS ($n=53$)	Conventional DP ($n=53$)	p value
	Mean ± SD or N (%)		
Estimated blood loss			
Ml	518.87 ± 510.726	626.47 ± 558.956	0.30
Operation time			
Min	262.75 ± 107.515	261.55 ± 99.392	0.95

RAMPS radical antegrade modular pancreatosplenectomy, *Conventional DP* conventional distal pancreatectomy, *POPF* postoperative pancreatic fistula, *SMV* superior mesenteric vein, *PV* portal vein

tumor features and metastatic lymph nodes (2.08 ± 2.663 vs 1.08 ± 1.90, $p=0.02$) than the conventional group, but there were no significant differences in intraoperative and postoperative outcomes; namely, complications, length of hospital stay, blood loss, and operation time, between the groups.

Postoperative recurrence patterns

Recurrence and R0 resection rates were not significantly different between the groups ($p=0.20$, $p=0.37$), but the recurrence patterns differed significantly between the groups. The conventional group had more local recurrence at the initial diagnosis of recurrence than the RAMPS group (32.3% vs 5.4%, $p=0.004$; Table 2). The regimen of postoperative chemotherapy included gemcitabine (50%, $n=54$) and a 5-FU based regimen (32%, $n=34$). We defined the absence of cancer cells in the margin (retroperitoneal margin, superior mesenteric vein groove) as R0 resection.

Prognostic impact of clinicopathologic features on pancreatic cancer in the propensity score-matched cohort

In the propensity score-matched analysis, there were no significant differences in T and N stages between groups (Table 3). The propensity score-matched cohort comprised 74 patients: 37 in the RAMPS group and 37 in the conventional group. After propensity-score matching, univariate analysis revealed node stage, tumor stage, and completion of chemotherapy as independent factors for poor RFS. On multivariate analyses, completion of chemotherapy was identified as an independent factor for poor RFS ($p<0.001$) (Table 4). After propensity-score matching, univariate analysis revealed T stage, N stage, tumor stage, cell differentiation, and completion of chemotherapy as independent factors for poor OS. On multivariate analysis, cell differentiation and completion of chemotherapy were identified as independent factors for poor OS ($p<0.001$; Table 5). Before propensity matching the mean levels of CA19-9 were 1504.25 [3.45–40350] in RAMPS and 190.84 [0.8–1728.6] in conventional DP.

Table 2 Postoperative recurrence patterns

	RAMPS ($n=53$)	Conventional DP ($n=53$)	p value
Recurrence rate			
Recurrence	37 (69.8%)	31 (58.5%)	0.20
No recur	12 (22.6%)	20 (37.7%)	
Unknown	4 (7.5%)	2 (3.8%)	
R0/1 rate			
R0	37 (69.8%)	41 (77.4%)	0.37
R1	16 (30.2%)	12 (22.6%)	
Chemotherapy completion rate			
Completion	26/43 (60.5%)	42/48 (87.5%)	0.003
No completion	17/43 (39.5%)	6/48 (12.5%)	
Recurrence pattern			
Local recurrence only	2/37 (5.4%)	10/31 (32.3%)	0.004
Local and distant recurrence	35/37 (94.6%)	21/31 (67.7%)	

RAMPS radical antegrade modular pancreatosplenectomy, *Conventional DP* Conventional distal pancreatectomy

Table 3 Clinical characteristics of the 106 patients with pancreatic cancer in the propensity matched cohort

	RAMPS ($n=37$)	Conventional DP ($n=37$)	p value
	Mean ± SD or N (%)		
Age	67.27 ± 9.29	64.30 ± 10.79	0.209
Sex			
Male	13 (35.1%)	21 (56.8%)	0.062
Female	24 (64.9%)	16 (43.2%)	
T stage, 8th			
T1	3 (8.1%)	3 (8.1%)	> 0.99
T2	21 (56.8%)	21 (56.8%)	
T3	13 (35.1%)	13 (35.1%)	
N stage, 8th			
N0	18 (48.6%)	18 (48.6%)	> 0.99
N1	15 (40.5%)	15 (40.5%)	
N2	4 (10.8%)	4 (10.8%)	
Stage, 8th			
IA	3 (8.1%)	3 (8.1%)	> 0.99
IB	10 (27%)	10 (27%)	
IIA	5 (13.5%)	5 (13.5%)	
IIB	15 (40.5%)	15 (40.5%)	
III	4 (10.8%)	4 (10.8%)	
Tumor size			
cm	3.79 ± 1.43	3.95 ± 2.27	0.209
Harvested lymph nodes	12.3 ± 8.38	13.27 ± 10.21	0.656
Metastatic lymph nodes	1.35 ± 2.03	1.38 ± 2.13	0.956
Perineural invasion			
Positive	30 (83.3%)	28 (75.7%)	0.418
Negative	6 (16.7%)	9 (24.3%)	
Lymphovascular invasion			
Positive	17 (45.9%)	15 (40.5%)	0.639
Negative	20 (54.1%)	22 (59.5%)	
Differentiation			
Well-Mod	33 (89.2%)	32 (86.5%)	> 0.99
Poorly-Undiff	3 (8.1%)	3 (8.1%)	
Unknown	1 (2.7%)	2 (5.4%)	
POPF			
No + Grade A	31 (83.8%)	36 (97.3%)	0.054
Grade B + C (clinically relevant POPF)	6 (16.2%)	1 (2.7%)	
Clavien dindo classification			
No	31 (83.8%)	36 (97.3%)	0.169
I-II	3 (8.1%)	0 (0%)	
III-IV	3 (8.1%)	1 (2.7%)	
Length of hospital stay			
days	13.11 ± 4.91	15.92 ± 15.98	0.312
SMV-PV resection			
Yes	3 (8.1%)	2 (5.4%)	> 0.99
No	34 (91.9%)	35 (94.6%)	
Other organ resection			
Yes	6 (16.2%)	5 (29.4%)	0.293
No	31 (83.8%)	12 (70.6%)	
Blood loss			
ml	458.11 ± 426.20	684.29 ± 619.85	0.078

Table 3 (continued)

	RAMPS ($n=37$)	Conventional DP ($n=37$)	p value
	Mean ± SD or N (%)		
Operation time			
min	269.84 ± 121.58	265 ± 108.70	0.859
Recurrence rate			
Recurrence	27 (73%)	23 (62.2%)	0.577
No recur	9 (24.3%)	12 (32.4%)	
Unknown	1 (2.7%)	2 (5.4%)	
R0/1 rate			
R0	27 (73%)	26 (72.2%)	0.943
R1	10 (27%)	10 (27.8%)	
Chemotherapy completion rate			
Completion	20 (66.7%)	27 (84.4%)	0.104
No completion	10 (33.3%)	5 (15.6%)	
Recurrence pattern			
Local recurrence only	2 (7.4%)	7 (30.4%)	0.062
Local and distant recurrence	25 (92.6%)	16 (69.6%)	

POPF postoperative pancreatic fistula, *SMV* superior mesenteric vein, *PV* portal vein, *RAMPS* radical antegrade modular pancreatosplenectomy, *Conventional DP* conventional distal pancreatectomy

After propensity matching, the mean levels of CA19-9 were 249.30 [3.45–2207] in the RAMPS group and 212.76 [0.8–1728.6] in the conventional DP group.

The main regimens of chemotherapy were gemcitabine- and 5-FU based. We analyzed the survival rate (RFS, OS) in the two groups, but found no significant difference between the groups in the propensity matching cohort.

RFS and OS after RAMPS vs. conventional DP in the propensity-score matched cohort

After propensity-score matching, the 3-year RFS rate was 19.9% (median RFS, 9.9 months; range 2.8–17.1 months) in the RAMPS group and 27.5% (median RFS, 10.4 months; range 7.3–13.5 months) in the conventional group. The 5-year OS rate was 14.2% (median OS, 27.5 months; range 13.7–41.3 months) in the RAMPS group and 29.9% (median OS, 25.5 months; range 17.1–33.8 months) in the conventional group. There was no significant difference in RFS or OS between the groups ($p=0.46$, $p=0.38$) (Figs. 1, 2).

Discussion

This study found no significant difference in DFS or OS between RAMPS and conventional DP. Moreover, our findings support the consensus that in pancreatic cancer treatment, postoperative chemotherapy is more important than the surgical procedure for prognosis.

Lymph node invasion and positive margin status are major predictors of recurrence and survival for patients undergoing surgery for pancreatic cancer [11–21]. A clear advantage of RAMPS over conventional DP is a large number of harvested lymph nodes and higher R0 resection rate [4–6]. In 2017, a meta-analysis by Cao et al. revealed that RAMPS was correlated with higher R0 resection rates and more successful harvesting of more lymph nodes than the standard procedure. However, no significant difference was found between the procedures with respect to RFS, OS, or disease-free survival [22]. In this study, the number of harvested lymph nodes and the number of metastatic lymph nodes were higher in the RAMPS group, but there was no significant difference in R0 resection rates between the groups because conventional DP was analogous to RAMPS (right to left dissection after pancreatic neck resection).

Many studies have compared these two surgical procedures by using historical controls; however, discrepancy between historical and concurrent controls led to a biased assessment of control response, thereby resulting in a biased assessment of the effectiveness of RAMPS. These discrepancies can be caused by improvements in clinical care from those practiced at the time of the historical trials [23]. Notably, the present multicenter study evaluated recent data within the same period, retrospectively, thus comparing the two surgical methods more objectively. Before propensity-score matching, the more advanced T and N stages were distributed in the RAMPS group. Because these stages were important factors affecting survival, T and N stages were used as covariates in the propensity-score matching analysis. A propensity-score matched cohort analysis was

Table 4 Univariate analysis (a) and multivariate analysis (b) of the relationship between recurrence-free survival and clinicopathologic variables by Cox regression hazard model in the propensity matched cohort

(a) Univariate analysis			
	HR	95%CI	*p* value
Age			
> 65			0.638
< 65	0.872	0.493–1.542	
Sex			
M			0.899
F	0.963	0.542–1.712	
T stage, 8th			
T1	1		
T2	2.358	0.716–7.770	0.159
T3	2.585	0.748–8.940	0.133
N stage, 8th			
N0	1		
N1	1.817	0.999–3.303	0.05
N2	1.380	0.471–4.044	0.557
Stage, 8th			
IA	1		
IB	1.731	0.482–6.219	0.4
IIA	2.411	0.597–9.743	0.217
IIB	3.083	0.921–10.323	0.068
III	2.325	0.519–10.409	0.270
Perineural invasion			
Negative	1		0.728
Positive	1.138	0.550–2.355	
Lymphovascular invasion			
Negative	1		0.604
Positive	1.163	0.658–2.055	
Differentiation			
Well-Mod	1		0.175
Poorly-Undiff	1.910	0.750–4.864	
R0/R1 resection			
R0	1		0.097
R1	1.673	0.911–3.073	
Operation type			
Conventional DP	1		0.464
RAMPS	1.236	0.701–2.181	
Chemotherapy completion			
No	1		< 0.001
Yes	0.264	0.128–0.545	
Regimen of chemotherapy			
5-FU	1		0.088
Gemcitabine	1.735	0.921–3.265	
(b) Multivariate analysis			
	HR	95% CI	*p* value
Age			
> 65			
< 65			

Table 4 (continued)

(b) Multivariate analysis

	HR	95% CI	*p* value
Sex			
M			
F			
T stage,8th			
T1			
T2			
T3			
N stage, 8th			
N0			
N1			
N2			
Stage, 8th			
IA	1		
IB	0.960	0.193–4.761	0.960
IIA	2.272	0.378–13.670	0.370
IIB	3.695	0.862–15.836	0.078
III	3.419	0.610–19.178	0.162
Perineural invasion			
Negative			
Positive			
Lymphovascular invasion			
Negative			
Positive			
Differentiation			
Well-Mod			
Poorly-Undiff			
R0/R1 resection			
R0			
R1			
Operation type			
Conventional DP			
RAMPS			
Chemotherapy completion			
No	1		< 0.001
Yes	0.142	0.056–0.361	
Regimen of chemotherapy			
5-FU			
Gemcitabine			

RAMPS Radical antegrade modular pancreatosplenectomy, *Conventional DP* Conventional distal pancreatectomy, *RFS* Recurrence-free survival

also performed to compare RAMPS and conventional DP, which revealed that only completion of chemotherapy was a significant independent factor for RFS and OS. The surgical procedures did not differ significantly in this regard. Our results confirmed that completion of chemotherapy was the most significant factor for the prognosis of left-side PDAC, in accordance with previous studies [24–30]. Postoperative adjuvant chemotherapy has increased survival significantly and is indispensable for patients with pancreatic cancer.

The complication rate of Clavien–Dindo classifications grade III and IV in our study was higher in the RAMPS group than in the conventional DP group. Poor physical status, such as malnutrition related to a high complication rate in the RAMPS group probably affected the completion rate

Table 5 Univariate analysis (a) and multivariate analysis (b) of the relationship between overall survival (OS) and clinicopathologic variables by Cox regression hazard model in the propensity matched cohort

(a) Univariate analysis			
	HR	95%CI	*p* value
Age			
> 65	1		0.603
< 65	0.859	0.485–1.523	
Sex			
M	1		0.605
F	0.858	0.479–1.535	
T stage, 8th			
T1	1		
T2	8.359	1.130–61.821	0.038
T3	10.339	1.370–78.050	0.024
N stage, 8th			
N0	1		
N1	3.138	1.627–6.054	0.001
N2	2.381	0.930–6.100	0.071
Stage, 8th			
IA	1		
IB	5.759	0.738–44.919	0.095
IIA	53,835	0.649–52.481	0.116
IIB	14.095	1.879–107.753	0.010
III	10.659	1.276–89.055	0.029
Perineural invasion			
Negative	1		0.140
Positive	1.910	0.809–4.508	
Lymphovascular invasion			
Negative	1	0.830–2.660	0.182
Positive	1.486		
Differentiation			
Well-Mod	1		0.047
Poorly-Undiff	2.600	1.012–6.676	
R0/R1 resection			
R0	1		0.135
R1	1.617	0.861–3.040	
Operation type			
Conventional DP	1		0.384
RAMPS	1.294	0.724–2.314	
Chemotherapy completion			
No	1		0.002
Yes	0.342	0.173–0.677	
Regimen of chemotherapy			
5-FU	1		0.098
Gemcitabine	1.701	0.907–3.190	
(b) Multivariate analysis			
	HR	95%CI	*p* value
Age			
> 65			
< 65			

Table 5 (continued)

(b) Multivariate analysis			
	HR	95%CI	*p* value
Sex			
M			
F			
T stage, 8th			
T1			
T2			
T3			
N stage, 8th			
N0			
N1			
N2			
Stage,8th			
IA	1		
IB	1.978	0.241–16.240	0.526
IIA	4.739	0.492–45.663	0.178
IIB	7.341	0.959–56.164	0.055
III	6.510	0.712–59.567	0.097
Perineural invasion			
Negative			
Positive			
Lymphovascular invasion			
Negative			
Positive			
Differentiation			
Well-Mod	1		0.027
Poorly-Undiff	3.121	1.141–8.538	
R0/R1 resection			
R0			
R1			
Operation type			
Conventional DP			
RAMPS			
Chemotherapy completion			
No	1		< 0.001
Yes	0.211	0.096–0.465	
Regimen of chemotherapy			
5-FU			
Gemcitabine			

RAMPS Radical antegrade modular pancreatosplenectomy, *Conventional DP* Conventional distal pancreatectomy, *OS* Overall survival

of postoperative adjuvant therapy; however, as this was a retrospective analysis, we do not know the exact correlation.

In our original collected data, there were 5 cases of borderline resectable PDAC (BR-PDAC) and 101 cases of resectable PDAC. However, after propensity matching, there were 3 cases of BR-PDAC and 71 cases of resectable PDAC. In the case of BR-PDAC, it was difficult to perform a subgroup analysis because the number of cases was too small.

This study has some limitations. First, although it was a multicenter study, it included data of patients from only two institutions and cannot reflect an analysis of the entire population of patients with pancreatic cancer. Second, because there were no clear indications for when to perform RAMPS or conventional DP, the potentially differing indications between the two hospitals may have introduced selection bias. Although we performed propensity score matching

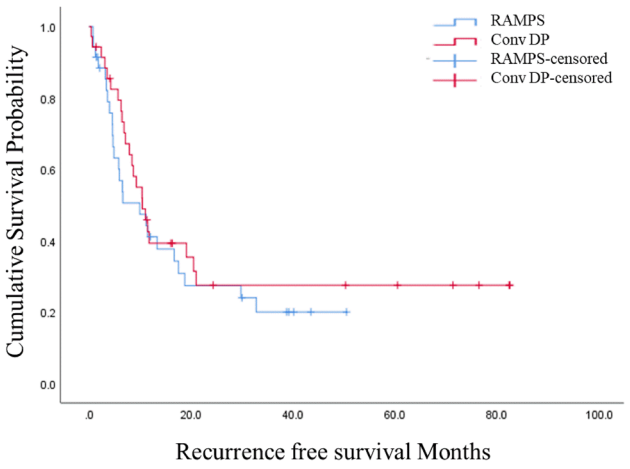

Fig. 1 Recurrence-free survival (RFS) after radical antegrade modular pancreatosplenectomy (RAMPS) vs. conventional distal pancreatectomy (DP) in the propensity-score matched cohort

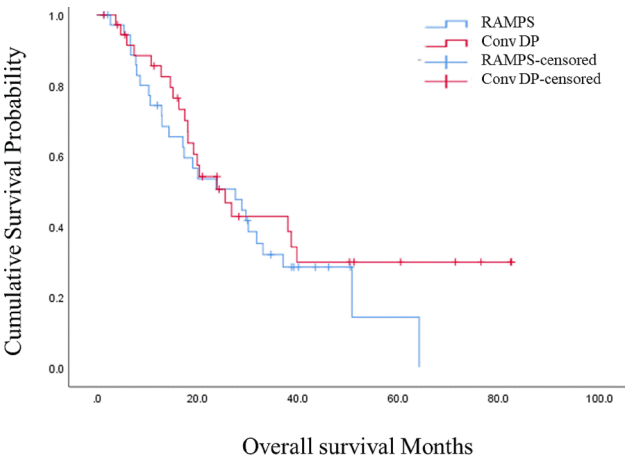

Fig. 2 Overall survival (OS) after radical antegrade modular pancreatosplenectomy (RAMPS) vs. conventional distal pancreatectomy (DP) in the propensity-score matched cohort

analysis to overcome this limitation, it was insufficient to allow us to evaluate the role of the RAMPS procedure for advanced-stage disease accurately because patients with the early-stage disease were included. Third, there were differences in methods of preoperative evaluation, treatment strategies, and surveillance between the two hospitals.

In conclusion, the disease-free survival and OS after RAMPS vs. conventional DP were not significantly different. RAMPS may be a better option for R0 resection in patients with advanced tumors; however, this is not unconditional in all patients undergoing DP for pancreatic cancer. Postoperative chemotherapy is more important than the surgical procedure for the prognosis of patients undergoing treatment for left-side pancreatic cancer. Based on the findings of our comparative analysis, the RAMPS procedure may be indicated for advanced tumors, defined as large tumors that are more likely to have a positive posterior margin.

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Declarations

Conflict of interest We have no competing interests to declare.

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