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Total laparoscopic versus robotic-assisted laparoscopic pancreaticoduodenectomy: which one is better?

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Abstract

Background Minimally invasive pancreaticoduodenectomy (MIPD) is a challenging procedure. Laparoscopic pancreaticoduodenectomy (LPD) is feasible and safe. Since the development of robotic platforms, the number of reports on robot-assisted pancreatic surgery has increased. We compared the technical feasibility and safety between LPD and robot-assisted LPD (RALPD).

Methods From September 2012 to August 2020, 257 patients who underwent MIPD for periampullary tumors were enrolled. Of these, 207 underwent LPD and 50 underwent RALPD. We performed a 1:1 propensity score-matched (PSM) analysis and retrospectively analyzed the demographics and surgical outcomes.

Results After PSM analysis, no difference was noted in demographics. Operation times and estimated blood loss were similar, as was the incidence of complications ($p > 0.05$). In subgroup analysis in patients with soft pancreas with pancreatic duct ≤ 2 mm, no significant between-group difference was noted regarding short-term surgical outcomes, including clinically relevant POPF (CR-POPF) ($p > 0.05$). In multivariable analysis, the only soft pancreatic texture was a predictive factor (HR 3.887, 95% confidence interval 1.121–13.480, $p = 0.032$).

Conclusion RALPD and LPD are safe and effective for MIPD and can compensate each other to achieve the goal of minimally invasive surgery.

Keywords Pancreaticoduodenectomy · Pancreatic fistula · Pancreaticojejunostomy · Pancreatic duct

Minimally invasive pancreaticoduodenectomy (MIPD) has been attempted in periampullary tumors since the first case of laparoscopic pancreaticoduodenectomy (LPD) was introduced by Dr. Gagner [1]. Several efforts have been taken to overcome the hurdles associated with MIPD. However, the technique has not been widely accepted in global healthcare centers because of its long learning curve [2]; this is related to the complex anatomy and technical difficulty associated with anastomosis, particularly in pancreaticojejunostomy (PJ) [3].

Although several challenges are associated with MIPD, a recent randomized controlled trial (RCT) that compared LPD and open pancreaticoduodenectomy (OPD) showed several advantages of MIPD, such as a shorter hospital stay and more favorable hospital course [4–6]. Recently, even in cases of pancreatic cancer, MIPD with vascular resection is being performed, and there are reports that it is more oncologically feasible and safe in well-selected patients than OPD [7, 8].

In our early experiences of robot-assisted LPD (RALPD) surgical robot systems were found to exhibit more advantages than laparoscopic surgery, including the ability to perform anastomosis using a three-dimensional (3D) magnified view, articulation of instruments with almost 540° of motion, and elimination of surgeon tremor [9]. Based on

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the advantages of the robotic system, recent RALPD can be performed by combining laparoscopic resection and robotic reconstruction [10].

The first RALPD was reported in 2003 by Giulianotti et al. and has propagated to widespread use; however, total LPD is also conducted at several centers and has numerous advantages [11]. In theory, robotic surgical systems have been introduced to overcome the limitations of laparoscopic surgery. However, robotic surgery is associated with several concerns, such as the lack of tactile sensation prompt, adequate management for urgent conversion, and the high cost of surgery, which can compromise the potential role of robotic surgery in MIPD.

Therefore, this study compared the perioperative outcomes of LPD and RALPD for periampullary tumors to ascertain which is the superior technique between the two.

Materials and methods

Study population and patient selection

From September 2012 to August 2020, 257 patients underwent MIPD for periampullary tumors at the Severance Hospital, Seoul, South Korea. Of these patients, the records of 207 (80.54%) who underwent LPD and 50 who underwent RALPD were retrospectively reviewed. The selection criteria for MIPD were ECOG 0–1, not severely obese, and vascular resection was not expected according to preoperative imaging studies. All patients provided informed consent before surgery, and this study was approved by the Institutional Review Board of Yonsei University College of Medicine. (registration date: August 17, 2021; registration number: 4-2021-0875).

Variables and outcome measures

Clinicopathological and intraoperative variables were collected retrospectively. Operative time was defined as the length of time from incision to skin closure and, therefore, included the time required to dock the robot. An R0 resection was defined as the absence of cancer cells under the microscope in the resected margin. The resection margins are composed of the transection margin (pancreatic duct, bile duct, proximal and distal duodenal margin) and the circumferential margins (posterior pancreatic surface, medial margin; groove along the superior mesenteric vein/portal vein, and anterior surface). Postoperative complications were classified according to the Clavien–Dindo Classification, such as postoperative pancreatic fistulas (POPF), delayed gastric emptying (DGE), and postpancreatectomy hemorrhage (PPH) were also classified according to the system of the International Study Group [12]. A re-operation was defined as any unplanned operation due to postoperative complications within 90 days of surgery. The definition of combined resection is accompanied by resection of adjacent organs outside the resection range of pancreaticoduodenectomy.

Surgical procedures

LPD and RALPD, end-to-side pancreaticojejunostomies, end-to-side hepaticojejunostomies, and side-to-side duodenojejunostomies were performed in the reconstruction phase. RALPD was performed in the same manner as LPD until the resection phase, and only the reconstruction phase was performed using a robotic system. Port placement and LPD were performed as detailed in a previously published report [13].

Statistical analysis

All statistical analyses were performed using SPSS statistical software (version 25.0; SPSS Inc., Chicago, IL, USA). Continuous variables are expressed as means ± standard deviations; categorical variables are represented as percentages or frequencies. The Mann–Whitney *U* test or Student's *t*-test was performed to compare continuous variables; Fisher's exact test or the chi-square test was used to compare categorical data. A Logistic regression analysis was applied to estimate the predictive factors for CR-POPF. p-value < 0.05 was considered to be statistically significant.

Propensity score-matched analysis

Propensity score-matched (PSM) analysis was performed to reduce the bias from several confounding variables. A propensity score was generated by binary logistic regression, and patients with similar propensity scores were then selected from the dataset (1:1 matching). Univariate and multivariate analyses were performed in the PSM population as well as the total population.

Results

Clinicopathologic characteristics

During the study period, 257 MIPDs were performed. Fifty patients underwent RALPD, and 207 underwent LPD. The mean patient age was 60.02 years in the RALPD group and 67.72 years in the LPD group ($p = 0.151$; Table 1). No significant difference was observed in sex distribution, body mass index, and ASA classification between the groups. No significant difference was observed between the groups regarding the pathologic diagnosis. Although there was no significant difference, cancers affecting the pancreas (23.19%), ampulla

Table 1 Clinicopathologic characteristics

	Total population			Propensity-matched population		
	LPD (n = 207)	RALPD (n = 50)	p-value	LPD (n = 50)	RALPD (n = 50)	p-value
Age	67.72 ± 11.87	60.02 ± 11.97	0.151	60.42 ± 11.14	60.02 ± 11.97	0.863
Sex			0.876			0.688
Male	105 (50.72)	26 (52.00)		29 (58.00)	26 (52.00)	
Female	102 (49.28)	24 (48.00)		21 (42.00)	24 (48.00)	
BMI	23.40 ± 2.88	23.57 ± 3.18	0.704	23.99 ± 2.29	23.57 ± 3.18	0.449
ASA class			0.317			0.735
1	16 (7.73)	5 (10.00)		5 (10.00)	5 (10.00)	
2	96 (46.38)	29 (58.00)		25 (50.00)	29 (58.00)	
3	94 (45.43)	16 (32.00)		20 (40.00)	16 (32.00)	
4	1 (0.48)	0 (0.00)		0 (0.00)	0 (0.00)	
Previous abdominal surgery			0.833			1.000
Laparoscopic	3 (1.45)	1 (2.00)		1 (2.00)	1 (2.00)	
Open	5 (2.42)	1 (2.00)		1 (2.00)	1 (2.00)	
Diagnosis			0.103			0.939
Pancreatic cancer	48 (23.19)	5 (10.00)		9 (18.00)	5 (10.00)	
NET	14 (6.76)	6 (12.00)		5 (10.00)	6 (12.00)	
IPMN	20 (9.66)	11 (22.00)		7 (14.00)	11 (22.00)	
AoV cancer	43 (20.77)	11 (22.00)		12 (24.00)	11 (22.00)	
CBD cancer	53 (25.60)	9 (18.00)		8 (16.00)	9 (18.00)	
Metastatic cancer	2 (0.97)	0 (0.00)		1 (2.00)	0 (0.00)	
Pancreatic cyst	10 (4.83)	4 (8.00)		4 (8.00)	4 (8.00)	
Duodenal cancer	5 (2.42)	0 (0.00)		1 (2.00)	0 (0.00)	
AoV adenoma	5 (2.42)	1 (2.00)		1 (2.00)	1 (2.00)	
Etc	7 (3.38)	3 (6.00)		2 (4.00)	3 (6.00)	
Neoadjuvant chemotherapy	10 (4.85)	1 (2.04)	0.480	3 (6.00)	1 (2.00)	0.617
Tumor size, cm	2.46 ± 1.30	2.29 ± 1.04	0.342	2.14 ± 1.24	2.29 ± 1.04	0.513
R-status			0.752			1.000
R0	192 (92.75)	47 (94.00)		47 (94.00)	47 (94.00)	
R1	14 (6.76)	3 (6.00)		2 (4.00)	3 (6.00)	
R2	1 (0.48)	0 (0.00)		1 (2.00)	0 (0.00)	
Pancreatic duct size, mm	3.65 ± 2.41	3.19 ± 2.19	0.226	3.33 ± 2.51	3.19 ± 2.17	0.766
Pancreas texture			0.018			1.000
Soft	148 (71.50)	44 (88.00)		44 (88.00)	44 (88.00)	
Hard	59 (28.50)	6 (12.00)		6 (12.00)	6 (12.00)	
Retrieved LN	11.10 ± 7.85	10.60 ± 6.79	0.687	9.74 ± 7.08	10.62	0.523
SMV-SV-PV confluence resection	14 (6.90)	3 (6.00)	1.000	3 (6.00)	3 (6.00)	1.000
Combined resection	3 (1.46)	0 (0.00)	1.000	2 (4.00)	0 (0.00)	0.495

ASA American society of anesthesiologists, *Aov* ampulla of vater, *BMI* body mass index, *LPD* laparoscopic pancreaticoduodenectomy, *LN* lymph nodes, *R-status* resection status, *RALPD* robot-assisted laparoscopic pancreaticoduodenectomy, *CBD* common bile duct, *IPMN* intraductal papillary mucinous neoplasm, *NET* neuroendocrine tumor; *SMV-SV-PV* superior mesenteric vein-splenic vein-portal vein

of Vater (20.77%), and common bile duct (25.60%) tended to be more common in the LPD group and intraductal papillary mucinous neoplasm (22.00%) tended to be more common in the RALPD group (Table 1).

No significant difference was noted in pathological outcomes between both platforms, except pancreatic texture ($p = 0.018$). In the total population, more cases of pancreatic hardness occurred in the LPD group than in the RALPD group ($p = 0.018$). Tumor size, resection status, pancreatic duct size, number of retrieved lymph nodes, and vascular resection rates were similar among the groups.

Short-term perioperative outcome

In the 1:1 PSM analysis, previously noted significant difference in terms of pancreatic texture disappeared ($p = 1.000$). Before the PSM analysis, the LPD group tended to have longer postoperative hospital stays than the RALPD group; however, after the PSM analysis, no significant difference was noted ($p = 0.832$). Postoperative complications such as POPF, DGE, and PPH also did not differ significantly between the groups. Within 90 days, there were 36 readmissions in the entire cohort, of which three were cases of clinically relevant POPF (CR-POPF), two involved gastrojejunostomy obstructions, and one was caused by pneumonia, the remaining readmissions were caused by poor oral intake and transient intestinal obstruction. There was one case of death caused by septic shock 15 days after surgery due to bile leakage and pneumonia (Table 2).

Subgroup analysis in soft remnant pancreas with pancreatic duct size < 2 mm

To investigate the potential role of robotic reconstruction in pancreatic ducts ≤ 2 mm, a subgroup analysis was performed in patients with soft remnant pancreas with pancreatic ducts ≤ 2 mm. The pancreatic ducts size was 1.67 ± 0.48 mm in the LPD group and 1.54 ± 0.54 mm in the RALPD group, with no significant difference between the groups ($p = 0.235$; Table 3). No significant difference was noted in the operation time and estimated blood loss (EBL) among the short-term operative outcomes between the two groups, or in the incidence of POPF, DGE, and PPH (Table 4). CR-POPF was found in 16.25% of patients in the LPD group and 8.00% in the RALPD group, with no significant difference between the groups ($p = 0.513$; Table 4).

Table 2 Short-term perioperative outcomes

	Total population			Propensity-matched population		
	LPD (*n* = 207)	RALPD (*n* = 50)	*p*-value	LPD (*n* = 50)	RALPD (*n* = 50)	*p*-value
Operation time, min	464.71 ± 76.06	445.86 ± 76.37	0.212	456.36 ± 78.65	445.86 ± 76.37	0.500
Estimated blood loss, ml	309.23 ± 324.04	246.20 ± 193.97	0.187	229.40 ± 237.11	246.20 ± 193.97	0.213
Intraoperative transfusion	5 (2.42)	1 (2.00)	1.000	2 (4.00)	1 (2.00)	1.000
Clavien–Dindo classification			0.511			0.061
I	71 (34.30)	17 (36.17)		18 (36.00)	17 (36.17)	
II	72 (34.78)	12 (25.53)		21 (42.00)	12 (25.53)	
IIIa	21 (10.14)	9 (19.15)		2 (4.00)	9 (19.15)	
IIIb	0 (0.00)	0 (0.00)		0 (0.00)	0 (0.00)	
IVa	2 (0.97)	0 (0.00)		0 (0.00)	0 (0.00)	
IVb	0 (0.00)	0 (0.00)		0 (0.00)	0 (0.00)	
V	2 (0.97)	0 (0.00)		0 (0.00)	0 (0.00)	
POPF			0.390			0.785
A	86 (41.55)	27 (54.00)		23 (46.00)	27 (54.00)	
B	25 (12.08)	6 (12.00)		7 (14.00)	6 (12.00)	
C	2 (0.97)	0 (0.00)		0 (0.00)	0 (0.00)	
CR-POPF	27 (13.05)	6 (12.00)	1.000	7 (14.00)	6 (12.00)	1.000
DGE			0.501			0.487
A	23 (11.11)	3 (6.00)		5 (10.00)	3 (6.00)	
B	5 (2.42)	0 (0.00)		1 (2.00)	0 (0.00)	
C	3 (1.45)	0 (0.00)		0 (0.00)	0 (0.00)	
PPH	5 (2.41)	1 (2.00)	1.000	2 (4.00)	1 (2.00)	1.000
Bile leakage	13 (6.28)	4 (8.00)	0.750	4 (8.00)	4 (8.00)	1.000
Chylous ascites	7 (3.38)	3 (6.00)	0.419	3 (6.00)	3 (6.00)	1.000
Wound complication	19 (9.18)	1 (2.00)	0.138	4 (8.00)	1 (2.00)	0.362
Re-operation	5 (2.42)	1 (2.00)	0.586	2 (4.00)	1 (2.00)	0.495
30 days mortality	1 (0.48)	0 (0.00)	1.000	0 (0.00)	0 (0.00)	1.000
Postoperative hospital stay, days	21.57 ± 14.00	18.42 ± 6.76	0.022	18.76 ± 9.09	18.42 ± 6.76	0.832
Readmission within 90 days	28 (13.53)	8 (17.02)	0.643	4 (8.00)	8 (17.02)	0.357

DGE delayed gastric emptying, *LPD* laparoscopic pancreaticoduodenectomy, *POPF* postoperative pancreatic fistula, *CR-POPF* clinically relevant POPF, *PPH* postpancreatectomy hemorrhage, *RALPD* robot-assisted laparoscopic pancreaticoduodenectomy

Table 3 Subgroup analysis in soft remnant pancreas with pancreatic ducts ≤ 2 mm: clinicopathologic and intraoperative characteristics

	LPD (n = 80)	RALPD (n = 25)	p-value
Age	58.41 ± 13.35	55.28 ± 14.34	0.317
Sex			0.498
Male	35 (43.75)	13 (52.00)	
Female	45 (56.25)	12 (48.00)	
BMI	23.90 ± 3.02	23.60 ± 3.08	0.669
ASA class			0.367
1	7 (8.75)	1 (4.00)	
2	51 (63.75)	20 (80.00)	
3	22 (27.50)	4 (16.00)	
4			
Previous abdominal surgery			1.000
Laparoscopic	1 (1.25)	0 (0.00)	
Open	1 (1.25)	0 (0.00)	
Diagnosis			0.235
Pancreatic cancer	11 (13.75)	0 (0.00)	
NET	8 (10.00)	5 (20.00)	
IPMN	4 (5.00)	2 (8.00)	
AoV cancer	14 (17.50)	4 (16.00)	
CBD cancer	24 (30.00)	7 (28.00)	
Metastatic cancer	0 (0.00)	0 (0.00)	
Pancreatic cyst	9 (11.25)	4 (16.00)	
Duodenal cancer	3 (3.75)	0 (0.00)	
AoV adenoma	4 (5.00)	0 (0.00)	
Etc.	3 (3.75)	3 (12.00)	
Tumor size, cm	2.56 ± 1.43	2.29 ± 1.22	0.403
R-status			0.492
R0	74 (92.50)	25 (100.00)	
R1	5 (6.25)	0 (0.00)	
R2	1 (1.25)	0 (0.00)	
Pancreatic duct size(mm)	1.67 ± 0.48	1.54 ± 0.54	0.235
Retrieved LN	8.95 ± 5.67	9.68 ± 5.91	0.579
Portal vein resection	3 (3.75)	1 (4.00)	1.000
Combined resection	1 (1.25)	0 (0.00)	1.000

ASA American society of anesthesiologists, *Aov* ampulla of vater, *BMI* body mass index, *LPD* laparoscopic pancreaticoduodenectomy, *LN* lymph nodes, *R-status* resection status, *RALPD* robot-assisted laparoscopic pancreaticoduodenectomy, *CBD* common bile duct, *IPMN* intraductal papillary mucinous neoplasm, *NET* neuroendocrine tumor

Determining the predicting factor for CR-POPF in MIPD

Soft pancreatic texture was found to be the only predicting factor for CR-POPF in the multivariable analysis (Hazard ratio 3.887, 95% confidence interval (95% CI): 1.124–13.480, $p = 0.032$). Age (odds ratio (OR) 1.014, 95% CI 1.038 (0.998–1.079, $p = 0.064$), and ASA class ≥ III (OR 0.439, 95% CI 0.183–1.052, $p = 0.065$) were noted to be marginally significant in predicting CR-POPF. However, the surgical approach (laparoscopic or robotic reconstruction) was not identified as a significant predicting factor for CR-POPF in MIPD (OR 0.909, 95% CI 0.354–2.337, $p = 0.843$; Table 5).

Discussion

This study aimed to determine which surgical procedure—LPD or RALPD—is more effective for patients with periampullary tumors. When comparing data using PSM analysis, no significant difference was found in short-term perioperative outcomes between LPD and RALPD. In addition, despite the well-known advantages of robot-assisted surgery, LPD and RALPD showed equivalent results in short-term operative outcomes, including postoperative hospital stay and the occurrence of CR-POPF in a small pancreatic duct ≤ 2 mm.

Although distal pancreatectomy has traditionally been performed using an open approach, minimally invasive approaches using laparoscopic or robot-assisted surgery have become increasingly popular over the past decade [14, 15]. A recent report from a multicenter patient-blinded RCT (LEOPARD), minimally invasive distal pancreatectomy (MIDP) reduces the time to functional recovery compared with open distal pancreatectomy. Although the overall rate of complications was not reduced, MIDP was associated with less DGE and better quality of life without increasing costs [16]. In contrast, MIPD is not generally accepted in global healthcare and has a long way to go in terms of technical and oncological safety [17].

Pancreaticoduodenectomy (PD) is divided into four types: OPD, total LPD, total robotic PD (RPD), and RALPD. Among these, the most effective type remains controversial, and the types of surgery performed according to the surgeon's preference are also heterogeneous. Several studies have been conducted to determine the most effective form of PD. In a meta-analysis of RCTs that compared LPD and OPD, no significant differences were noted between LPD and OPD in terms of postoperative complications and mortality. However, the lack of clinical and statistical homogeneity between studies does not allow for any definitive conclusion regarding the role of LPD [18].

Among the several advantages of robotic surgical systems, the articulation of instruments with almost 540° of motion and elimination of surgeon tremors can facilitate anastomosis in the reconstruction phase of PD, and RALPD is being conducted in some institutions [19, 20]. However, few studies on the comparison between RALPD and LPD have been published.

In Liu et al.'s study that compared 27 cases of RALPD and 25 cases of LPD, the LPD group showed significantly

Table 4 Subgroup analysis in soft remnant pancreas with pancreatic ducts ≤ 2 mm: short-term operative outcomes

	LPD (*n* = 80)	RALPD (*n* = 25)	*p*-value
Operation time, min	471.50 ± 83.41	437.16 ± 69.41	0.065
Estimated blood loss, ml	289.25 ± 236.70	246.40 ± 196.70	0.414
Intraoperative transfusion	3 (3.75)	1 (4.00)	1.000
Clavien–Dindo classification			0.559
I	32 (40.00)	9 (36.00)	
II	28 (35.00)	6 24.00)	
IIIa	10 (12.50)	5 (20.00)	
IIIb	0 (0.00)	0 (0.00)	
IVa	0 (0.00)	0 (0.00)	
IVb	0 (0.00)	0 (0.00)	
V	1 (1.25)	0 (0.00)	
POPF			0.387
A	46 (57.50)	18 (72.00)	
B	13 (16.25)	2 (8.00)	
C	0 (0.00)	0 (0.00)	
DGE			0.880
A	10 (12.50)	2 (8.00)	
B	2 (2.50)	0 (0.00)	
C	1 (1.25)	0 (0.00)	
PPH	4 (5.00)	1 (4.00)	1.000
Bile leakage	3 (3.75)	3 (12.00)	0.145
Chylous ascites	1 (1.25)	2 (8.00)	0.140
Wound complication	7 (8.75)	1 (4.00)	0.677
Re-operation	4 (5.00)	0 (0.00)	0.570
30 days mortality	0 (0.00)	0 (0.00)	1.000
Postoperative hospital stay, day	21.23 ± 16.21	19.12 ± 8.00	0.534
Readmission within 90 days	12 (15.00)	4 (16.00)	1.000
CR-POPF	13 (16.25)	2 (8.00)	0.513

CR-POPF clinically relevant postoperative pancreatic fistula, *DGE* delayed gastric emptying, *LPD* laparoscopic pancreaticoduodenectomy, *POPF* postoperative pancreatic fistula, *PPH* postpancreatectomy hemorrhage, *RALPD* robot-assisted laparoscopic pancreaticoduodenectomy

Table 5 Multivariable analysis of the predictive factors of CR-POPF from logistic regression analysis

	Univariable analysis		Multivariable analysis	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age	1.014 (0.982–1.048)	0.393	1.038 (0.998–1.079)	0.064
BMI	1.095 (0.972–1.234)	0.137		
Pancreas texture, soft	3.827 (1.127–12.994)	0.031	3.887 (1.121–13.480)	0.032
P-duct size ≤ 2 mm	0.997 (0.478–2.076)	0.993		
Intraoperative transfusion	3.548 (0.624–20.187)	0.153		
ASA class ≥ III	0.529 (0.241–1.164)	0.114	0.439 (0.183–1.052)	0.065
Operation time	1.002 (0.997–1.007)	0.415		
Robotic reconstruction	0.909 (0.354–2.337)	0.843		

95% CI 95% confidence interval, *ASA* American society of anesthesiologists; *BMI* body mass index, *CR-POPF* clinically relevant postoperative pancreatic fistula, *OR* odds ratio, *P-duct* pancreatic duct

longer operative times (mean, 387 vs. 442 min) and longer hospital stays (mean 24 vs. 17 days) than the RALPD group ($p < 0.05$). The intraoperative EBL was significantly lesser in the RALPD group than in the laparoscopic group ($p < 0.05$) [21]. In Park et al.'s study that compared LPD and 49 RALPD in 43 cases, RALPD showed better results in terms of the operation time, anastomosis time, and wound infection rate [20].

Referring to the recent learning curve analysis [2, 22], in Liu et al.'s study, the LPD group ($n = 25$) did not meet the number of cases required to surmount the learning curve [21]. In the study by Park et al., an appropriate comparison could not be conducted by excluding all open conversion cases [20]. As mentioned in the previous report regarding the learning curve, the present study comparatively analyzed the results of RALPD performed by a surgeon who performed at least 100 cases of the challenging period through PSM analysis showed equivalent results. In addition, RALPD and LPD showed equivalent results in cases of small pancreatic ducts.

In the resection phase, LPD enables faster replacement of the camera and other surgical instruments and enhanced operator response compared to RALPD and has the advantage of being able to respond immediately to difficulties during surgery. However, there are ergonomic difficulties in the reconstruction phase, and it takes much time to overcome the learning curve. The robotic system can reduce the operator's burden by enabling a fixed field and elaborate motion more suitable for the reconstruction phase. However, this study showed that RALPD and LPD could produce equivalent operative outcomes regardless of the pancreatic duct size, despite the advantages of the robotic system.

In this study, multivariable analysis for a predictive factor of CR-POPF showed that age, ASA classification, and soft pancreatic texture were marginal predictive factors. This is quite different from the findings of other studies and should be considered in developing a CR-POPF prediction model for MIPD [23, 24]. In addition, based on this, patient selection for safe MIPD is considered necessary.

The goal of MIPD is to provide patients with a less invasive procedure to confer beneficial surgical outcomes. LPD can benefit disease-free survival in well-selected patients compared to OPD in pancreatic cancer, and the conversion rate has an adverse effect on surgical and oncologic outcomes [25–28]. Therefore, to reduce conversion and fulfill the purpose of minimally invasive surgery, it is crucial to have the ability to perform laparoscopic reconstruction techniques that can solve problems occurring during robotic reconstruction after performing laparoscopic resection. A surgeon capable of only robotic reconstruction may need unnecessary open conversion because laparoscopic compensation is not available. The perioperative outcomes of surgeons who received training for LPD and RALPD at the same time were compared, and both RALPD and LPD showed feasible results regardless of pancreatic duct size. In addition, there are many comparative papers between pure robotic PD and LPD; however, few studies on the comparison between RALPD and LPD have been published.

There are some inherent limitations of this study. First, this was conducted as a single-center retrospective study. Second, because robotic surgery is associated with high costs in Korea's insurance system, a selection bias may exist in selecting patients with a low probability of open conversion so that the operation does not fail.

In conclusion, both RALPD and LPD are safe and effective approaches for PD and are technically similar regardless of the pancreatic duct size. In order to satisfy the goal of MIPD and considering the high cost of robotic surgery, it is essential that HBP surgeons can perform both LPD and RALPD. Additionally, surgeons need to identify how MIPD can be safely administered to a patient using these two surgical methods rather than determining the superior technique.

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Declarations

Disclosures Drs. Munseok Choi, Seoung Yoon Rho, Sung Hyun Kim, Ho Kyoung Hwang, Woo Jung Lee, Chang Moo Kang have no conflicts of interest or financial ties to disclose.

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