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Comparison of perioperative short-term outcomes and oncologic long-term outcomes between open and laparoscopic distal pancreatectomy in patients with pancreatic ductal adenocarcinoma

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Purpose: Laparoscopic distal pancreatectomy (LDP) is widely performed but its efficacy and safety are not established for malignant lesions. This study was aimed to compare outcomes of LDP and open distal pancreatectomy (ODP) in pancreatic ductal adenocarcinoma (PDAC).
Methods: Patients who underwent distal pancreatectomy for PDAC between 2009 and 2017 were enrolled. The preoperative clinical stage was evaluated and propensity score matching (PSM) was performed using age, sex, The American Joint Committee on Cancer 8th clinical T stage, and other organ involvement.
Results: In 186 patients enrolled, 35 (18.8%) received LDP. The ODP group showed larger tumor size and frequent involvement of other organs in preoperative images. However, after PSM, these differences were balanced. R0 resection (90.5% *vs*. 94.3%, P = 0.730), harvested lymph nodes (14.3 *vs*. 12.6, P = 0.380) and pathologic T stage (P = 0.474) were comparable between ODP and LDP groups, respectively. LDP demonstrated shorter operation time, less postoperative pain, and shorter hospitalization (14.4 days *vs*. 11.1 days, P = 0.026). In terms of long-term oncologic outcomes, median overall survival (32 months *vs*. 28 months, P = 0.724) and disease-free survival (18 months *vs*. 19 months, P = 0.926) were comparable.
Conclusion: LDP demonstrated better short-term outcomes and comparable long-term outcomes compared with ODP. LDP is a safe and feasible procedure for PDAC.
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Key Words: Laparoscopy, Pancreatectomy, Pancreatic carcinoma, Survival analysis

INTRODUCTION

Laparoscopic surgery has been proven beneficial in various malignant lesions of the digestive system. For gastric cancer, laparoscopic gastrectomy has been widely used and has demonstrated better outcomes compared with conventional open surgery [1,2]. The advantages of laparoscopic surgery for colorectal cancer have also been established by several randomized controlled trials [3-6]. In contrast, there is no high-level evidence for the efficacy and safety of laparoscopic surgery in pancreatic cancer, and its feasibility also remains controversial.

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Despite these controversies regarding laparoscopic pancreatectomy for pancreatic cancer, the use of laparoscopic pancreatectomy has been expanded constantly. Laparoscopic pancreaticoduodenectomy is generally performed by several experts due to its complexity [7,8]. Compared to laparoscopic pancreaticoduodenectomy, laparoscopic distal pancreatectomy (LDP) is widely performed because it does not require complicated reconstruction.

The efficacy and safety of LDP for benign or borderline diseases were proven by a randomized controlled trial (RCT) that compared it with open distal pancreatectomy (ODP) [9]. The authors reported a shorter time to functional recovery and a better quality of life after LDP. In contrast, in the case of malignant pancreatic lesions, there are no RCTs on the long-term oncologic outcomes; there are only retrospective studies investigating the short-term and long-term outcomes of LDP and ODP [10-15]. In the case of retrospective studies, the treatment-selection bias was inevitable which prevented meaningful comparisons. Therefore, statistical methods to minimize the impact of treatment selection must be used.

Therefore, the purpose of this study was to evaluate the safety and feasibility of LDP for pancreatic ductal adenocarcinoma (PDAC) by comparing perioperative short-term outcomes and oncologic long-term outcomes using the propensity score matching (PSM) method.

METHODS

Patients

This study was a retrospective cohort study with prospectively collected data. Patients who underwent distal pancreatectomy (DP) at Seoul National University Hospital (Seoul, Korea) between January 2009 and December 2017 were reviewed. Patients who underwent curative-intent surgery with pathologically confirmed PDAC were included in the current study. Patients with distant metastasis, double primary lesions, or those receiving neoadjuvant treatment for improved tumor resectability were excluded. LDP was performed in patients with a lesion which was localized in the pancreatic parenchyma without pancreatitis and involvement of adjacent organ such as colon and stomach on preoperative CT images. In addition, there was no evidence for invasion of major vessels including celiac artery, common hepatic artery, and superior mesenteric artery. Body mass index (BMI) was not restricted in selecting patients to receive LDP. None of them received neoadjuvant therapy before surgery. Open conversion cases, for any reason, were included in the ODP group. This study was approved by the Institutional Review Board of Seoul National University Hospital (No. SNUH-2007-095-1141) with a waiver for informed consent.

Clinicopathologic data

The baseline characteristics were investigated including age, sex, BMI, American Society of Anesthesiologists (ASA) physical status, and underlying disease. All patients received CT or MRI before surgery to determine the preoperative clinical stage. Images of all cases were reviewed for tumor size and involvement of other organs or splenic vessels. Tumor markers including CA 19-9 and CEA were also checked before surgery.

Perioperative clinical outcomes including operation-related data, pathologic data, and clinical outcomes were investigated. Postoperative pain was estimated according to the numeric rating scale (NRS) on postoperative day (POD) 1 and 3. Duration of postoperative hospital stay and interval from operation to adjuvant treatment were investigated. To evaluate long-term oncologic outcomes, median overall survival (OS), median disease-free survival (DFS), 5-year OS rate, and 5-year DFS rate were investigated.

Operation procedure and postoperative management

During the dissection around the distal pancreas, lymph nodes (LNs) in the inferior pancreatic, splenic arterial, gastrosplenic, and splenic hilar area were routinely dissected. Pancreas transection was performed on the superior mesenteric vein with as endoscopic triple-line linear stapler (Endo-GIA, Autosuture Corp., Norwalk, CT, USA; Echelone-Flex, Ethicon, Somerville, NJ, USA). In ODP patients, we used the same stapling method or sewed by hand. If the patient was suspected to have or was diagnosed with PDAC before surgery, spleen preservation was not attempted. Combined organ resection was defined as resection of other organs such as the adrenal gland or colon, excluding the spleen.

All patients were managed with similar postoperative treatment. CT was performed for every patient POD 4 to detect clinically relevant postoperative pancreatic fistula (CR-POPF) and other complications. The amylase level was also checked using blood serum and intraabdominal fluid from drainage. The CR-POPF grade was defined according to the International Study Group on Pancreas Surgery criteria [16].

Statistical analysis

Continuous variables were expressed as the mean and standard deviation (SD) and were analyzed with the Student t-test or Mann-Whitney U-test as appropriate. Categorical variables were compared using the chi-squared test or Fisher exact test.

Matching between the ODP and LDP patients was performed by estimating a propensity score for each patient and matching the patients from each group in a 3:1 ratio. To estimate the propensity score, a logistic regression model using 4 covariates was performed. Each patient who underwent LDP was matched

to a patient who underwent ODP by using nearest neighbor matching at a ratio of 3:1 within a specified caliper width. This matching was performed without replacement and by using a caliper width of 0.2 SDs of the logit of the estimated propensity score.

Survival analysis was performed using the Kaplan-Meier estimated survival. Statistical significance was defined as $P < 0.05$. To determine the independent prognostic factors for survival outcomes, multivariate analysis was performed. A Cox proportional hazards model was used for multivariable analysis. All statistical calculations were made using the IBM SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Patients and preoperative clinical evaluation

A total of 233 patients diagnosed with PDAC underwent DP between January 2009 and December 2017. Among these patients, 25 patients with distant metastasis or double primary tumor and 22 patients who received neoadjuvant therapy were excluded. Consequently, 186 patients were enrolled in this study, of whom 35 patients (18.8%) received LDP and 151 patients (81.2%) received ODP. There were 2 open conversion cases, the first patient was due to bleeding and the second patient was due to superior mesenteric vein involvement.

The baseline characteristics and preoperative clinical findings of each group are shown in Table 1. The demographics including age, sex, BMI, ASA physical status, underlying disease, and previous abdominal operation history were comparable between the ODP and LDP groups.

In preoperative evaluation, patients in the ODP group tended to show larger tumor size on CT images compared with patients in the LDP group (3.0 cm *vs.* 2.6 cm, respectively; $P = 0.064$). There were also differences in the composition of clinical T (cT) stage and invasion into other organs on preoperative imaging between the ODP and LDP groups, which were not statistically significant. The number of patients who demonstrated higher than the normal levels of tumor markers, such as CA 19-9 and CEA, was comparable between the ODP and LDP groups.

To make the composition of patients comparable, we performed PSM with 4 variables which revealed differences between the ODP and LDP groups, including age, sex, cT stage, and other organ involvement. After PSM, differences in preoperative clinical evaluation between the ODP and LDP

Table 1. Baseline characteristics and preoperative clinical findings

Characteristic	Before propensity score matching			After propensity score matching		
	ODP	LDP	P-value	ODP	LDP	P-value
No. of patients	151	35		105	35	
Age (yr)	67.3 ± 9.6	65.7 ± 11.2	0.405	66.2 ± 9.7	65.7 ± 11.2	0.814
Male sex	84 (55.6)	21 (60.0)	0.638	59 (56.2)	21 (60.0)	0.844
Body mass index (kg/m^2)	22.9 ± 3.0	23.2 ± 3.3	0.638	22.8 ± 3.1	23.2 ± 3.3	0.538
ASA PS classification			0.966			0.983
I	39 (25.8)	9 (25.7)		27 (25.7)	9 (25.7)	
II	101 (66.9)	23 (65.7)		70 (66.7)	23 (65.7)	
III	11 (7.3)	3 (8.6)		8 (7.6)	3 (8.6)	
Underlying disease						
Hypertension	67 (44.4)	17 (48.6)	0.653	40 (38.1)	17 (48.6)	0.275
Diabetes mellitus	57 (37.7)	11 (31.4)	0.562	38 (36.2)	11 (31.4)	0.685
Previous abdominal surgery history	49 (32.5)	8 (22.9)	0.314	36 (34.3)	8 (22.9)	0.293
Tumor size on image (cm)	3.0 ± 1.3	2.6 ± 1.1	0.064	2.6 ± 1.2	2.6 ± 1.1	0.868
cT stage			0.159			0.553
cT1	34 (22.5)	14 (40.0)		34 (32.4)	14 (40.0)	
cT2	87 (57.6)	17 (48.6)		62 (59.0)	17 (48.6)	
cT3	27 (17.9)	4 (11.4)		9 (8.6)	4 (11.4)	
cT4	3 (2.0)	0 (0)		0 (0)	0 (0)	
Other organ involvement	21 (13.9)	2 (5.7)	0.258	5 (4.8)	2 (5.7)	0.823
Splenic artery involvement	68 (45.0)	12 (34.3)	0.263	35 (33.3)	12 (34.3)	0.918
Splenic vein involvement	86 (57.0)	14 (40.0)	0.090	52 (49.5)	14 (40.0)	0.328
CA 19-9, >37 U/mL	102 (67.5)	21 (60.0)	0.395	66 (62.9)	21 (60.0)	0.763
CEA, >5 ng/mL	26 (17.2)	3 (8.6)	0.301	15 (14.3)	3 (8.6)	0.761

Values are presented as number only, mean ± standard deviation, or number (%).
ODP, open distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; ASA, American Society of Anesthesiologists; PS, physical status; cT stage, clinical T stage.

groups were balanced. Tumor size and involvement of other organs became comparable on preoperative imaging between the ODP and LDP groups.

Perioperative clinicopathologic outcomes

Perioperative short-term clinical outcomes including pathologic findings are shown in Table 2. Before PSM, LDP demonstrated shorter operation time and less combined organ resection compared with ODP. The mean estimated blood loss was comparable between the ODP and LDP groups. After PSM, the mean operation time of LDP was shorter than that of ODP (170 minutes *vs.* 128 minutes, respectively; P = 0.001).

The pathologic findings including R0 resection rate (90.5% *vs.* 94.3%, respectively; P = 0.730), tumor size, and the mean number of harvested and metastatic LNs were comparable between the ODP and LDP groups. There were also no significant differences in the pathologic T (pT) and pathologic N stage between groups.

For pain after surgery, the mean NRS of the ODP was higher than that of LDP patients on POD 1 and POD 3. During the hospital stay, 22 patients (14.6%) in the ODP group and 4 patients (11.4%) in the LDP group had complications. The CR-POPF rates were comparable between the ODP and LDP groups (8.6% *vs.* 2.9%, P = 0.475). Patients in the LDP group demonstrated a shorter duration of hospital stay than those in the ODP group (15.0 days *vs.* 11.1 days, respectively; P = 0.031). Also, interval time between surgery and adjuvant treatment was shorter in LDP group (44.6 days *vs.* 38.4 days, respectively; P = 0.022). After PSM, patients in the LDP group still demonstrated less postoperative pain on POD 1 and POD 3 and a shorter duration of postoperative hospital stay and interval from surgery to adjuvant treatment.

Oncologic long-term outcomes

Regarding the entire cohort, the median OS was 30 months and the 5-year OS rate was 31.1%. The median DFS was 16

Table 2. Perioperative clinicopathologic outcomes

Variable	Before propensity score matching			After propensity score matching		
	ODP (n = 151)	LDP (n = 35)	P-value	ODP (n = 105)	LDP (n = 35)	P-value
Operation time (min)	175 ± 64	128 ± 40	0.001	170 ± 64	128 ± 40	0.001
Combined organ resection	33 (21.9)	2 (5.7)	0.030	16 (15.2)	2 (5.7)	0.242
Estimated blood loss (mL)	265 ± 287	235 ± 240	0.567	252 ± 229	235 ± 240	0.718
Resection status			0.536			0.730
R0	134 (88.7)	33 (94.3)		95 (90.5)	33 (94.3)	
R1	17 (11.3)	2 (5.7)		10 (9.5)	2 (5.7)	
Tumor size (cm)	3.4 ± 1.5	3.2 ± 1.4	0.369	3.2 ± 1.5	3.2 ± 1.4	0.982
Pathologic T stage			0.188			0.474
pT1	14 (9.3)	7 (20.0)		13 (12.4)	7 (20.0)	
pT2	89 (58.9)	19 (54.3)		67 (63.8)	19 (54.3)	
pT3	48 (31.8)	9 (25.7)		25 (23.8)	9 (25.7)	
No. of LNs						
Harvested LN	14.4 ± 9.6	12.6 ± 8.1	0.312	14.3 ± 10.0	12.6 ± 8.1	0.380
Metastatic LN	1.52 ± 2.0	1.57 ± 2.4	0.902	1.3 ± 2.0	1.6 ± 2.4	0.568
pN stage			0.993			0.817
pN0	63 (41.7)	15 (42.9)		51 (48.6)	15 (42.9)	
pN1	66 (43.7)	15 (42.9)		39 (37.1)	15 (42.9)	
pN2	22 (14.6)	5 (14.3)		15 (14.3)	5 (14.3)	
Numeral rating scale						
POD 1	5.8 ± 1.4	5.2 ± 1.2	0.023	5.9 ± 1.4	5.2 ± 1.2	0.012
POD 3	4.3 ± 1.1	3.5 ± 0.8	0.001	4.3 ± 1.1	3.5 ± 0.8	0.001
Complication, CD grade ≥IIIa	22 (14.6)	4 (11.4)	0.790	16 (15.2)	4 (11.4)	0.782
Clinically relevant POPF	13 (8.6)	1 (2.9)	0.475	7 (6.7)	1 (2.9)	0.679
Postoperative hospital stay (day)	15.0 ± 9.9	11.1 ± 6.7	0.031	14.4 ± 7.7	11.1 ± 6.7	0.026
Adjuvant chemotherapy	117 (77.5)	31 (88.6)	0.168	83 (79.0)	31 (88.6)	0.210
Adjuvant radiation therapy	72 (47.7)	24 (68.6)	0.038	53 (50.5)	24 (68.6)	0.078
Interval from operation to adjuvant treatment (day)	44.6 ± 13.9	38.4 ± 9.2	0.022	45.3 ± 13.5	38.4 ± 9.2	0.011
Recurrence	98 (64.9)	22 (62.9)	0.820	64 (61.0)	22 (62.9)	0.841

Values are presented as mean ± standard deviation or number (%).
ODP, open distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; LN, lymph node; pN stage, pathologic N stage; POD, postoperative day; CD, Clavien-Dindo classification; POPF, postoperative pancreatic fistula.

months and the 5-year DFS rate was 23.8%. Before PSM, survival outcomes of the ODP group were comparable with those of the LDP group (Fig. 1). The median OS in the ODP and LDP group was 30 and 28 months, respectively (P = 0.879), and the median DFS was 16 and 19 months, respectively (P = 0.672). After PSM, there was no difference in survival outcomes between the ODP and LDP groups (Fig. 2). The median OS in the ODP and LDP group was 32 and 28 months, respectively (P = 0.724), and the median DFS was 18 and 19 months, respectively (P = 0.926). The OS and DFS of a patient who underwent open conversion due to major vessel invasion were 12 months. The OS and DFS of the other patient who underwent open conversion due to intraabdominal bleeding were 46 and 18 months. In addition, as we performed survival analysis including 2 open conversion cases into LDP group, the median OS and DFS was 28 months and 18 months, respectively. These results were also comparable with ODP group.

The recurrence rate and recurrence patterns are shown in Table 3. After PSM, there was no significant difference in the overall recurrence rate, and the type of recurrence between the ODP and LDP groups (58.9% *vs.* 62.9%, respectively; P = 0.670).

Further analysis was performed to identify the factors that affect the survival outcomes. In univariate and multivariate analysis, the age (hazard ratio [HR], 1.818; P = 0.002) and pT

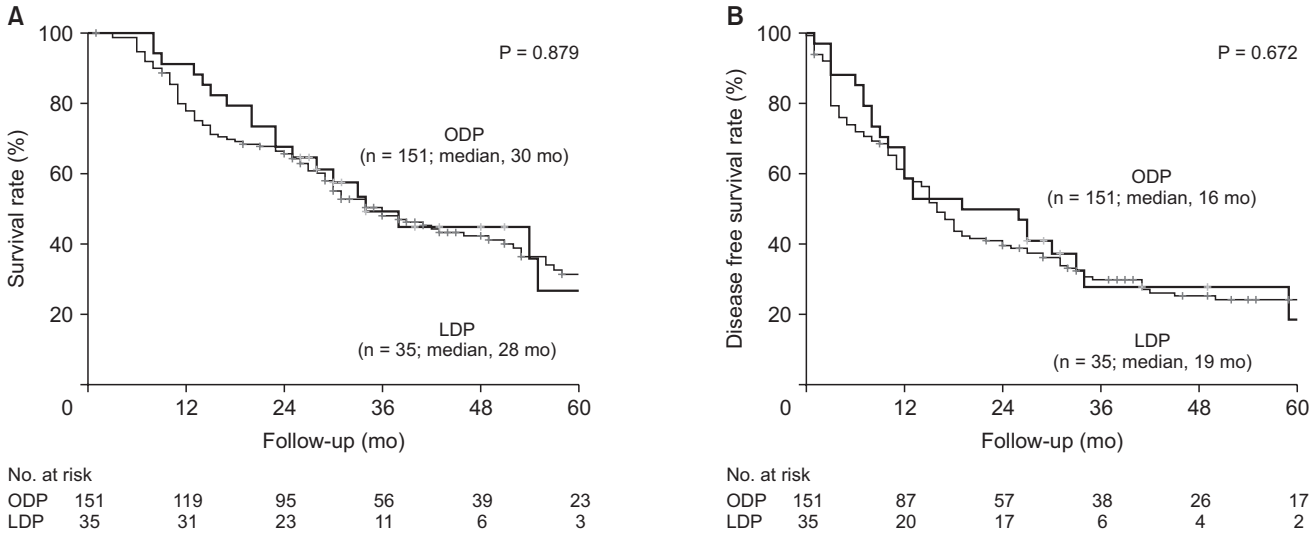

Fig. 1. The Kaplan-Meier survival curve of open (ODP) and laparoscopic distal pancreatectomy (LDP) before propensity score matching (PSM). Before PSM, (A) overall survival and (B) disease-free survival between ODP and LDP patients were comparable.

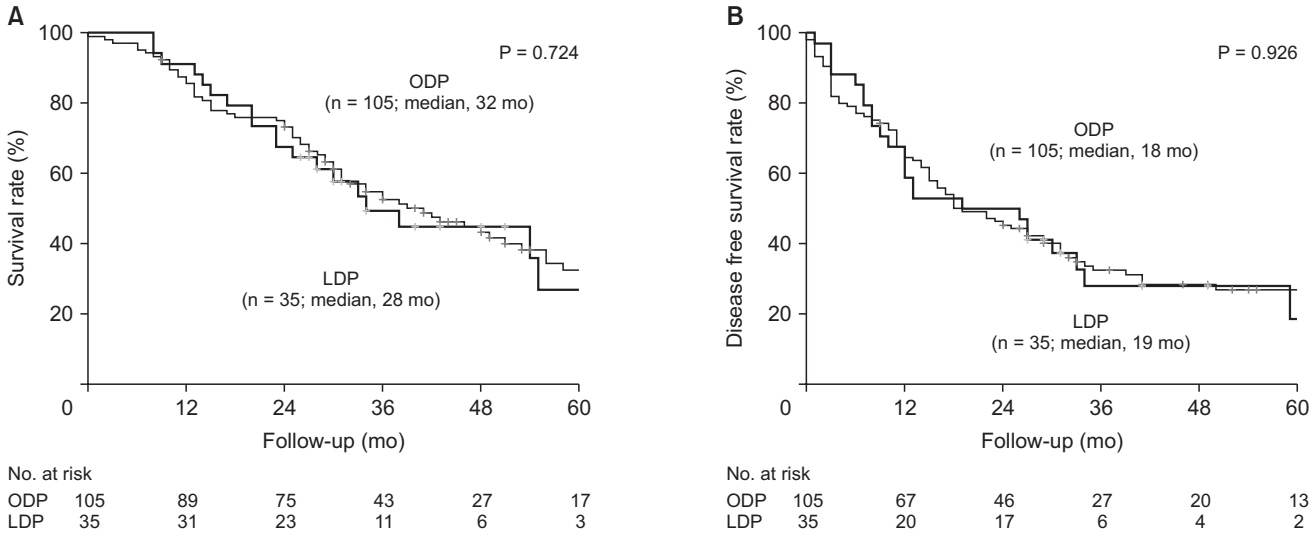

Fig. 2. The Kaplan-Meier survival curve of open (ODP) and laparoscopic distal pancreatectomy (LDP) after propensity score matching (PSM). After PSM, (A) overall survival and (B) disease-free survival between ODP and LDP patients were comparable.

Table 3. Recurrence patterns between open and laparoscopic distal pancreatectomy in resected pancreas body and tail cancer

Variable	Before propensity score matching			After propensity score matching		
	ODP (n = 151)	LDP (n = 35)	P-value	ODP (n = 105)	LDP (n = 35)	P-value
Overall recurrence	98 (64.9)	22 (62.9)	0.820	64 (61.0)	22 (62.9)	0.841
Recurrence type			0.208			0.185
Local recurrence	9 (9.2)	0 (0)		7 (10.9)	0 (0)	
Systemic recurrence	89 (90.8)	22 (100)		57 (89.1)	22 (100)	

Values are presented as number (%).
ODP, open distal pancreatectomy; LDP, laparoscopic distal pancreatectomy.

Table 4. Prognostic factors in resected pancreas body and tail cancer

Factor	Univariate analysis			Multivariate analysis		
	No. of patients (n)	5-YSR (%)	P-value	Hazard ratio	95% CI	P-value
Age (yr), ≤70/>70	112/74	37.6/18.9	0.006	1.863	1.27–2.72	0.001
Sex, male/female	105/81	30.0/31.5	0.377			
ASA PS classification, I/II/III	48/124/14	36.8/32.7/10.0	0.513			
Preoperative CA 19-9 (ng/mL), ≤37/>37	52/88	36.0/28.1	0.093	1.412	0.92–2.17	0.115
Preoperative CEA (IU/mL), ≤5/>5	121/19	29.8/45.1	0.990			
Preoperative organ involvement, –/+	163/23	32.4/22.3	0.044	1.191	0.66–2.15	0.561
Operation type, OPD/LDP	151/35	31.6/27.0	0.879			
R0/R1	167/19	32.2/15.0	0.329			
pT stage			0.002			<0.001
pT1	21	60.0				
pT2	108	30.5	0.047	2.326	1.07–5.07	0.034
pT3	57	23.4	0.002	3.992	1.78–8.95	0.001
LN metastasis, –/+	78/108	35.1/28.2	0.091	1.158	0.76–1.76	0.488
Combined organ resection, –/+	151/35	33.4/20.2	0.015	1.161	0.71–1.91	0.554
Adjuvant chemotherapy, –/+	38/148	20.7/34.3	0.088	0.688	0.43–1.10	0.118
Adjuvant radiotherapy, –/+	90/96	26.5/34.3	0.234			

5-YSR, 5-year survival rate; CI, confidence interval; ASA, American Society of Anesthesiologists; PS, physical status; ODP, open distal pancreatectomy; LDP, laparoscopic distal pancreatectomy; pT stage, pathologic stage; LN, lymph node.

stage (T2: HR, 2.326; P = 0.034; T3: HR, 3.992; P = 0.001) were identified as prognostic factors for 5-year OS rate in patients who received DP for PDAC (Table 4). However, the type of surgery had no impact on survival outcomes (P = 0.879).

DISCUSSION

LDP has been widely performed by pancreatic surgeons because it does not require reconstruction and is technically easier than pancreaticoduodenectomy. Although there is no oncologic high-level evidence to support the benefits of laparoscopic surgery in pancreatic cancer, pancreatic surgeons have made a continuous effort to establish the advantages of LDP by comparing surgical outcomes with ODP. However, meaningful comparisons in previous studies have been prevented by the small cohort sizes and the treatment-selection bias of retrospective studies. Therefore, the current study was designed to minimize selection bias by using PSM to compare perioperative short-term and oncologic long-term outcomes of ODP and LDP in matched cohorts of PDAC patients.

Treatment-selection bias occurred before surgery because the surgeon decided which patients would undergo ODP or LDP by preoperative images. Patients who showed larger tumor size or invasion into other organs tended to undergo ODP, rather than LDP. Although RCT is well known to be the most powerful method for minimizing the impact of selection bias, the small number of cases and the disastrous prognosis of pancreatic cancer make it difficult to design RCT. Therefore, we performed PSM with variables including age, sex, cT stage, and other organ involvement evaluated by preoperative images. After PSM, differences in preoperative findings between ODP and LDP were balanced.

In early laparoscopic surgery, pancreatic surgeons were concerned about oncologic safety in terms of R0 resection

and adequate lymphadenectomy, which were known to be important prognostic factors of PDAC [17-20]. It is more difficult to obtain a negative resection margin and adequate lymphadenectomy in pancreatic cancer compared with other gastrointestinal cancers due to its anatomical position, major adjacent vessels, and extensive surgical range. However, surgeons have constantly striven to prove the oncologic safety of LDP against ODP in PDAC patients. Zhang et al. [21] investigated 98 patients with PDAC, in which 22 patients underwent LDP. They reported 87% *vs.* 91% R0 resection rates, and mean number of harvested LNs in ODP and LDP patients, respectively. In our study, R0 resection rates and the mean number of harvested LNs were also comparable between the ODP and LDP groups. Consequently, LDP is an appropriate method for obtaining oncological clearance in terms of the negative resection margin and the sufficient number of harvested LNs.

In propensity-matched patients, those patients who received LDP demonstrated less pain and shorter hospitalization after surgery. Many studies also reported early recovery and shorter hospital stay following LDP compared to ODP in PDAC patients [22-24]. These were results of minimal manipulation of organs during surgery and smaller surgical wounds due to the laparoscopic approach. These improved short-term outcomes could lead to improved oncologic long-term outcomes. Early recovery after surgery facilitates administration of proper adjuvant chemotherapy, which has significant survival benefits for patients with pancreatic cancer [25,26]. Neoptolemos et al. [27] reported that the 5-year survival rate was 21% among 147 resected pancreatic cancer patients who received chemotherapy and 8% among 142 patients who did not receive chemotherapy ($P = 0.009$). In our study, LDP group demonstrated shorter interval from surgery to adjuvant treatment. Therefore, early recovery after LDP could theoretically be related to better survival outcomes.

The comparable survival outcomes between ODP and LDP patients are consistent with other reports in the literature. Shin et al. [24] from Asan Medical Center in Korea reported that 1-, 2-, and 5-year OS rates were 87.6%, 64.3%, and 32.5% in 70 LDP patients which were comparable with ODP group ($P = 0.250$). Also, van Hilst et al. [23] reported median OS was 31 months in 340 LDP patients and 28 months in 856 ODP patients. These results were due to similar pathologic findings with the LDP and ODP group, such as R0 resection rate, tumor size, and the number of metastatic LNs. Furthermore, a similar extent and procedure of surgery between the ODP and LDP groups could lead to comparable survival outcomes. Although most studies reported comparable survival outcomes between these 2 groups, Sulpice et al. [28] reported improved survival of LDP patients over ODP patients. They reported that median survival was 62.5 months for 347 LDP patients and 36.7 months for 2,406 ODP patients. They explained that these results were due to selection bias or a lower incidence of splenectomy and blood transfusion of LDP patients. However, there were no statistical methods to reduce selection bias between the 2 groups. In our study, a patient age greater than 70 years, and the pT stage of PDAC were also independently associated with OS. Kooby et al. [10] also reported risk factors for patients with PDAC including advanced patient age, larger tumor size, LN and margin positive resections, and absence of adjuvant therapy.

The present study does have some limitations. First, selection bias could have occurred since the majority of patients in the LDP group may have been selected due to having a small tumor without invasion into other organs. Although PSM was performed, it was impossible to completely eliminate the impact of treatment selection bias. Second, as a limitation of the retrospective study, surgeons performed LDP for more advanced cases in the latter part of the study period. However, most of the LDP was performed according to the inclusion criteria. Last, LDP tended to be performed more recently than ODP. In 2009, the first case of LDP was performed and the ratio of LDP over ODP was 7.1%. The ratio of LDP over ODP increased gradually, reaching 17.1% in 2016 and 25.7% in 2017. These trends potentially resulted in bias due to improvement of surgical technique and perioperative management, such as chemotherapy and radiation therapy.

In conclusion, patients in the LDP group showed better perioperative short-term outcomes in terms of the operation time, postoperative pain, and hospital stay compared with the ODP group. In terms of oncologic long-term outcomes, median OS and DFS were comparable. Therefore, LDP can be used as a safe and feasible surgery for PDAC patients.

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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Methodology: All authors
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