pISSN: 2508-5778 • eISSN: 2508-5859
Ann Hepatobiliary Pancreat Surg 2024;28:220-228
https://doi.org/10.14701/ahbps.23-144

AHBPS
Annals of Hepato-Biliary-Pancreatic Surgery

Original Article

Comparison of short-term outcomes of open and laparoscopic assisted pancreaticoduodenectomy for periampullary carcinoma: A propensity score-matched analysis

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Backgrounds/Aims: Postoperative pancreatic fistula is the key worry in the ongoing debate about the safety and effectiveness of total laparoscopic pancreaticoduodenectomy (TLPD). Laparoscopic-assisted pancreaticoduodenectomy (LAPD), a hybrid approach combining laparoscopic resection and anastomosis with a small incision, is an alternative to TLPD. This study compares the short-term outcomes and oncological efficacy of LAPD vs. open pancreaticoduodenectomy (OPD).
Methods: A retrospective analysis of data of all patients who underwent LAPD or OPD for periampullary carcinoma at a tertiary care center in Northeast India from July 2019 to August 2023 was done. A total of 30 LAPDs and 30 OPDs were compared after 1:1 propensity score matching. Demographic data, intraoperative and postoperative data (30 days), and pathological data were compared.
Results: The study included a total of 93 patients, 30 underwent LAPD and 62 underwent OPD. After propensity score matching, the matched cohort included 30 patients in both groups. The LAPD presented several advantages over the OPD group, including a shorter incision length, reduced postoperative pain, earlier initiation of oral feeding, and shorter hospital stays. LAPD was not found to be inferior to OPD in terms of pancreatic fistula incidence (Grade B, 30.0% vs. 33.3%), achieving R0 resection (100% vs. 93.3%), and the number of lymph nodes harvested (12 vs. 14, $p = 0.620$). No significant differences in blood loss, short-term complications, pathological outcomes, readmissions, and early (30-day) mortality were observed between the two groups.
Conclusions: LAPD has comparable safety, technical feasibility, and short-term oncological efficacy.

Key Words: Pancreaticoduodenectomy; Propensity score; Laparoscopy

INTRODUCTION

Open pancreaticoduodenectomy (OPD) has been the standard of care in the surgical management of patients with periampullary carcinoma (PAC) [1,2]. However, minimally invasive surgery for PAC has grown in popularity and acceptance over the last decade with the benefits of decreased blood loss, less postoperative pain, early initiation of oral nutrition, and shorter hospital stays [3,4]. Despite advances in minimally invasive techniques, theincidence of postoperative pancreatic fistula (POPF) still ranges between 3% to 45% in high-volume institutions [5-7]. Pancreatoenteric anastomosis is considered the Achilles heel of pancreatoduodenectomy (PD); the associated morbidity andmortality of POPF outweigh the advantages of laparoscopic PD.

The laparoscopic pancreatoenteric anastomosis remains limited and its safety and efficacy remain debatable because, unlike open technique, with laparoscopic pancreatojejunostomy, it is challenging to perform precise anastomosis resulting in increased rates of POPF and restricting patient selection in the total laparoscopic pancreaticoduodenectomy (TLPD)

Received: November 7, 2023, **Revised:** January 28, 2024,
Accepted: January 30, 2024, **Published online:** February 22, 2024

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group (small size tumor, early-stage tumor, hard pancreas, and dilated pancreatic duct). In addition, there are increased rates of other postoperative complications such as delayed gastric emptying (DGE) and post-pancreatectomy hemorrhage (PPH) [8]. Notably, the majority of the evidence on TLPD comes from high-volume centers with super-selective cases [9-11].

Laparoscopic-assisted pancreaticoduodenectomy (LAPD), is a hybrid surgery that combines the advantages of laparoscopic resection and overcomes the difficulty in performing a precise anastomosis through a small midline laparotomy avoiding the technically arduous laparoscopic reconstruction. This can serve as a bridge in the learning curve in the transition from OPD to TLPD. However, there is a scarcity of data comparing the outcomes of the LAPD and OPD [8]. The majority of data are non-randomized retrospective data and there are few high-quality comparison research studies [12-14]. This study aimed to compare short-term outcomes and oncological efficacy of the LAPD versus OPD using a propensity score matching analysis.

MATERIALS AND METHODS

The medical records of all patients who had undergone PD at a tertiary care center in Northeast India between July 1, 2019 and August 31, 2023 were retrospectively reviewed. Patients included in the study had either a clinical and radiological suspicion of periampullary mass or a preoperative histological diagnosis of PAC. We initially performed OPD cases in the first two years of the study period and subsequently transitioned to LAPD. The inclusion criteria of patients in both groups were nonmetastatic, resectable PAC-encompassing pancreatic head (within 2 cm of the ampulla), duodenum, ampulla of Vater, and distal common bile duct. There were no specific inclusion criteria for the LAPD group. The resectability criteria followed the National Comprehensive Cancer Network Guidelines for pancreatic tumors using standard preoperative pancreatic protocol computerized tomography scan [15]. Patients with locally advanced disease, borderline resectable tumors (according to NCCN criteria), prior neoadjuvant therapy, and those who required vascular resection were excluded from both groups. Additionally, patients presenting with multiple comorbidities and prior major abdominal surgery were not considered for LAPD. Patients were provided with detailed information about the LAPD and OPD procedures. The operating surgeon made the final decision of LAPD versus OPD during the initial staging laparoscopy considering tumor factors and adhesions.

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institute Ethical Board Committee, All India Institute of Medical Sciences, Patna, India (Protocol code -IEC/2022/1043). Informed consent was taken from all participants involved in the study. Following the institutional ethical committee review board approval, parameters such as patient demographics, comorbidities, preoperative blood indices, need for preoperative biliary drainage, duration of surgery after biliary drainage, intraoperative details, early postoperative outcomes, and histopathological data were analyzed between the two groups. Of the 110 PD patients 92 patients had PD done for PAC, of which 30 underwent LAPD and 62 underwent OPD, as shown in Fig. 1. To minimize the possibility of selection bias, a propensity score-matching study was carried out using logistic regression analysis. This was because variables like age, sex, body mass index (BMI), comorbidity index, preoperative pathology (PAC), biliary drainage, and clinical complaints could influence the outcome of surgery.

All the LAPD and OPD operations were performed by the same team of surgeons. Standard open pylorus resecting PD was performed using the bilateral subcostal approach. LAPD comprised the laparoscopic phase of mobilization, lymph nodal dissection, and specimen transection. The specimen was then placed in a specimen-extracting bag. Subsequently, reconstruction was performed through an upper midline incision of 6–7 cm, and the specimen was retrieved externally. The reconstruction technique was similar in both groups. It included two-layer duct to mucosa pancreatojejunostomy without any internal stent placement or dunking/invagination technique for nondilated pancreatic duct, single-layer interrupted hepaticojejunostomy, and ante colic two-layer gastrojejunostomy. A single abdominal drain is placed in the right subhepatic space.

Operative time was measured from the initial trocar insertion (LAPD) or skin incision (OPD) until the closure of the skin. The estimated blood loss was calculated as the total

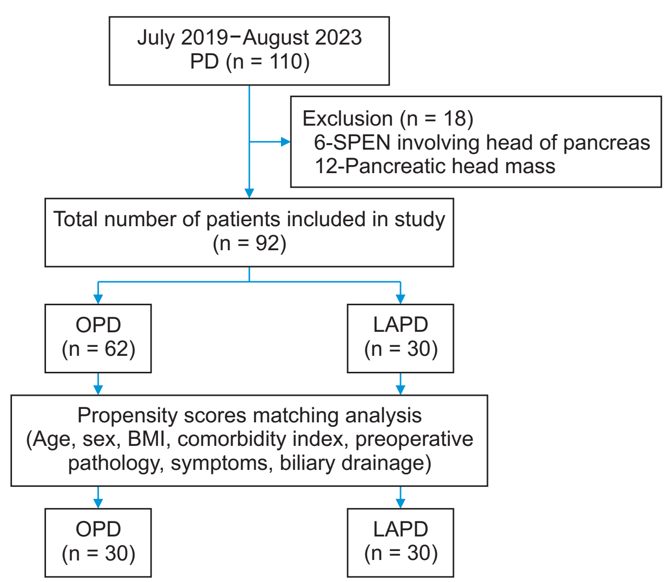

Fig. 1. Flow diagram of patient inclusion criteria. PD, pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy; LAPD, laparoscopic assisted pancreaticoduodenectomy; BMI, body mass index; SPEN, solid pseudopapillary epithelial neoplasm.

volume of fluids collected in the suction device, in addition to the weight of gauze and towels used during the procedure. The conversion from laparoscopic to an open procedure was defined as the shift to a laparotomy before reaching the dissection of mid-pancreatic tissue, without regard to the specific level of the laparotomy. Postoperative complications were evaluated following the Clavien–Dindo classification and encompassed issues such as POPF, DGE, bile leaks, PPH, intraabdominal collections, and surgical site infections. These complications were categorized into grades A, B, and C, as outlined by the International Study Group of Pancreatic Surgery (ISGPS) guidelines [16-18]. Reoperation was defined as a subsequent surgical procedure necessitated within 30 days of the LAPD due to significant complications. Morbidity and mortality refer to the occurrence of adverse health outcomes or fatal outcomes during or within 30 days after surgery. The final pathological diagnosis was established by using the American Joint Committee on Cancer (AJCC) cancer staging manual, considering the tumor's size, grade, pathological type, lymphovascular invasion, perineural invasion, total number of lymph nodes inspected, and margin status. Surgical resections were categorized as R0 if no cancer was detected in any of the margins, R1 if cancer was discovered within 1 mm of the resected margins, and R2 if there was cancer in any of the margins. The histopathological examination of PD specimens followed the American College of Pathologists Protocol [19].

Statistical analysis

The LAPD group was compared with the OPD group in a 1:1 association. matched demographic, surgical, and postoperative characteristics were compared between the two groups using bivariate analysis. Continuous variables were presented as mean ± standard deviation or median (interquartile range [IQR]) based on the normality of the data. The Fisher exact test or Chi-square test was used to test the statistical significance of cross-tabulation of categorical variables. A t-test was used to compare the continuous variables between the two groups to ascertain their mean (standard deviation). The median (IQR) of continuous variables was compared between the two groups using the Mann–Whitney U test. A p-value < 0.05 was considered statistically significant. Data analysis was carried out using SPSS 20.0 (SPSS Inc.).

Table 1. Comparison of demographic and preoperative parameters between two groups before and after propensity matching

Parameter	All patient			After propensity matching		
	LAPD (n = 30)	OPD (n = 62)	p-value	LAPD (n = 30)	OPD (n = 30)	p-value
Age (yr)	49.53 ± 12.73	50.21 ± 11.53	0.799	49.53 ± 12.73	48.60 ± 10.25	0.756
Sex			0.012			0.071
Male	11 (36.7)	40 (64.5)		11 (36.7)	18 (60.0)	
Female	19 (63.3)	22 (35.5)		19 (63.3)	12 (40.0)	
BMI (kg/m^2)	21 (20–22)	21 (20–22)	0.159	21 (20–22)	21 (20–22)	0.260
ASA			0.351			0.593
Class I	18 (60.0)	39 (62.9)		18 (60.0)	18 (60.0)	
Class II	11 (36.7)	23 (37.1)		11 (36.7)	12 (40.0)	
Class > III	1 (3.3)	0 (0)		1 (3.3)	0 (0)	
Preoperative Hb (g/dL)	10.77 ± 1.14	11.38 ± 1.17	0.020	10.77 ± 1.14	11.36 ± 1.17	0.052
Preoperative total bilirubin (mg/dL)	11.23 (7.73–14.96)	11.98 (6.8–16.7)	0.809	11.23 (7.73–14.96)	9.85 (6.2–13.8)	0.267
Preoperative direct bilirubin (mg/dL)	7.21 (4.4–10.4)	7.55 (3.4–9.8)	0.626	7.21 (4.4–10.4)	5.75 (3.2–8.9)	0.318
Preoperative albumin (g/dL)	3.34 (3.12–3.6)	3.12 (2.99–3.4)	0.090	3.34 (3.12–3.6)	3.12 (2.98–3.52)	0.129
Prothrombin time (sec)	15.1 ± 3.1	14 ± 2.55	0.114	15.1 ± 3.1	13.8 ± 2.05	0.078
Pancreatic duct diameter (mm)	4.75 (2–6)	4 (3–7)	0.853	5 (2–6)	4 (3.0–5.4)	0.927
Preoperative biliary drainage	22	40		22	18	
ERCP	16 (53.3)	31 (50.0)	0.764	16 (53.3)	14 (46.7)	0.606
PTBD	6 (20.0)	9 (14.5)	0.714	6 (20.0)	4 (13.3)	0.488
Preoperative symptoms						
Jaundice	30 (100)	58 (93.5)	0.300	30 (100)	29 (96.7)	0.996
Weight loss	26 (86.7)	62 (100)	0.010	26 (86.7)	30 (100)	0.112
Recurrent fever	16 (53.3)	34 (54.8)	0.892	16 (53.3)	15 (50.0)	0.998
Comorbidity index	2.3 ± 1.1	2.2 ± 1.3	0.653	2.3 ± 1.1	2.3 ± 1.4	0.996

Values are presented as mean ± standard deviation, number (%), mean (range), or number only.
BMI, body mass index; ASA, American Society of Anesthesiologists; ERCP, endoscopic retrograde cholangiopancreatography; PTBD, percutaneous transhepatic biliary drainage; LAPD, laparoscopic assisted pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy.

Table 2. Comparison of perioperative outcomes between LAPD and OPD groups after propensity scoring

Parameter	LAPD (n = 30)	OPD (n = 30)	*p*-value
Duration of surgery after biliary drainage (mon)	2 (2–3)	2 (2–2)	0.315
Operative time (min)	463.80 ± 40.94	359.00 ± 45.89	< 0.001
Intraoperative blood transfusion	24 (80.0)	22 (73.3)	0.542
Estimated blood loss (mL)	400 (300–500)	350 (300–500)	0.259
Pancreas texture (soft)	16 (53.3)	15 (50.0)	0.796
Postoperative ICU stay (day)	2 (2–2)	2 (2–3)	0.005
Time to passage of flatus (day)	4 (3–4)	4 (4–4)	0.035
Time to oral intake (day)	5 (4–6)	6 (5–7)	< 0.001
Length of hospital stay (day)	8 (7–9)	10 (9–12)	< 0.001
Length of incision (cm)	6 (6–7)	17 (16–18)	< 0.001
Postoperative pain (VAS)	5 (3–6)	7 (6–9)	< 0.001

Values are presented as mean (range), mean ± standard deviation, or number (%).
LAPD, laparoscopic assisted pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy; ICU, intensive care unit; VAS, visual analog scale.

RESULTS

Following propensity matching, 60 patients were divided into two groups: 30 patients in the LAPD and the OPD group. Covariates were compared between the groups, before and after matching. Table 1 displays the demographic and preoperative variables for both groups before and after propensity score matching. The mean age of the patients was 49.53 ± 12.73 years in the LAPD group and 48.60 ± 10.25 years in the OPD group. The distribution of male and female patients in the LAPD and OPD groups was 36.7%, 63.3%, and 60%, 40% ($p = 0.071$). Jaundice and weight loss were the predominant symptoms. Preoperatively, there was no significant difference in the mean total bilirubin between the LAPD and OPD groups (11.23 [7.73 to 14.96] vs. 9.85 [6.2 to 13.8], $p = 0.267$). Patients' BMI, American Society of Anesthesiologists (ASA) grade, pancreatic duct diameter, rate of preoperative biliary drainage, and Charlson comorbidity index did not differ significantly between the groups [20].

Table 2 displays the perioperative outcomes for the two groups after propensity matching. The LAPD group had a longer operative time in comparison to the OPD group 463.80 ± 40.94 vs. 359.00 ± 45.89 ($p < 0.001$). The LAPD group exhibited several advantages over the OPD group, including the shorter incision (6 cm vs. 17 cm, $p < 0.001$), less postoperative pain, visual analog scale score (5 vs. 7, $p < 0.001$), initiation of early oral feeding (5 days vs. 6 days, $p < 0.001$), and shorter hospital stays (8 days vs. 10 days, $p < 0.001$). No significant differences were noted in blood loss, intraoperative blood transfusions, pancreatic texture, and need for intensive care unit stay between the groups. The duration of surgery after biliary drainage was the same in both groups.

Table 3 provides an overview of the surgical outcomes and short-term complications in the two groups following propensity matching. The short-term postoperative surgical complications, POPF, DGE, PPH, bile leak, intrabdominal collections, wound infection, and pulmonary infection, did not exhibit significant differences between the two groups. POPF was the most common complication in both groups; Grade A POPF accounted for 66.7% and 63.3% in the LAPD group and OPD group, respectively. Grade B POPF was observed in 30% of the LAPD cases and 33.3% in the OPD cases, but there were no instances of Grade C POPF. DGE was the second most common

Table 3. Comparison of short-term complications and surgical outcomes between LAPD and OPD after propensity matching

Parameter	LAPD (n = 30)	OPD (n = 30)	*p*-value
POPF			
Grade A	20 (66.7)	19 (63.3)	0.787
Grade B	9 (30.0)	10 (33.3)	0.781
PPH			
Grade A	0 (0)	3 (10.0)	0.237
DGE	20 (66.7)	25 (83.3)	0.136
Grade A	11 (36.7)	10 (33.3)	0.787
Grade B	9 (30.0)	15 (50.0)	0.114
Clavien–Dindo			
Grade > III	9 (30.0)	15 (50.0)	0.08
Radiological intervention for intrabdominal collection	9 (30.0)	13 (43.3)	0.284
Bile leak	2 (6.7)	2 (6.7)	0.997
Pulmonary infection	3 (10.0)	5 (16.7)	0.704
Abdominal collection	9 (30.0)	13 (43.3)	0.417
Wound infection	12 (40.0)	12 (40.0)	0.998
Re-exploration	0 (0)	2 (6.7)	0.492
30-day mortality	0 (0)	1 (3.3)	0.998

Values are presented as number (%).
LAPD, laparoscopic assisted pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy; POPF, postoperative pancreatic fistula; PPH, post pancreatectomy hemorrhage; DGE, delayed gastric emptying.

complication. Grade A DGE accounted for 36.7% and 33.3% in the LAPD and OPD groups, respectively, and it responded well to conservative measures and prokinetic agents. Grade B DGE occurred in 30% of LAPD cases and 50% of OPD cases. A total of 9 patients in the LAPD group and 13 in the OPD group with Grade B DGE had an intraabdominal collection that required an additional image-guided percutaneous drainage. Two patients in each group experienced bile leaks, which spontaneously resolved. In the OPD group, postoperative bleeding was observed in three patients due to bleeding from the gastroduodenal artery (GDA) stump, pancreatic cut surface, and small bowel mesentery. Postoperative bleeding occurred early in 2 patients (< 24 hours) and 1 patient had delayed presentation (48 hours). Two patients had undergone reexploration for bleeding on postoperative day (POD) 2 and another patient underwent angiographic coil embolization for GDA stump bleeding on POD 4. According to Clavien–Dindo's classification, only two patients in the OPD group had Grade III complications that necessitated surgical intervention, and no significant differences were noted in the incidence of postoperative complications between the two groups. There was one (3.3%) 30-day mortality in the OPD group. One death occurred on POD 3 in a patient who underwent OPD for T3N2M0 with sepsis and disseminated intravascular coagulation. Overall severe complications did not significantly differ between the two groups. Although the differences in abdominal infections were not statistically significant between the two groups (30% vs. 40%, p = 0.417), the LAPD group had a lesser incidence and severity. Three cases in the LAPD group underwent conversion to OPD, two cases with suspected portal vein involvement, and one case with uncontrolled hemorrhage during uncinate dissection.

While there were variations in tumor size, grade, pathological type, AJCC T, and N staging, perineural invasion, lymphatic spread, and R0 resection, no statistically significant changes were seen in TNM staging or pathological outcomes. Two patients in the OPD group had positive pancreatic resection margin (adenocarcinoma). The total number of lymph nodes harvested did not differ between the two groups (LAPD, 12 vs. 14, p = 0.620). Five patients in the LAPD group and seven patients in the OPD group had perineural invasion, which can influence long-term survival. Additional histopathological outcomes are shown in Table 4.

Table 4. Comparison of TNM staging and pathologic outcomes between the LAPD group and OPD group of unmatched and matched groups

Parameter	LAPD (n = 30)	OPD (n = 62)	*p*-value	LAPD (n = 30)	OPD (n = 30)	*p*-value
Tumor size (cm)						
< 1	4 (13.3)	10 (16.1)	0.968	4 (13.3)	5 (16.7)	0.996
1–2	7 (23.3)	17 (27.4)	0.676	7 (23.3)	8 (26.7)	0.766
> 2	19 (63.3)	35 (56.5)	0.530	19 (63.3)	17 (56.7)	0.598
Pathological type			0.848			0.881
Intestinal	21 (70.0)	38 (61.2)		21 (70.0)	22 (73.3)	
Pancreaticobiliary	4 (13.3)	12 (19.3)		4 (13.3)	5 (16.6)	
Mixed	3 (10.0)	8 (12.9)		3 (10.0)	2 (6.6)	
Mucinous adenocarcinoma	2 (6.6)	4 (6.5)		2 (6.6)	1 (3.3)	
AJCC T staging			0.955			0.650
T1	6 (20.0)	12 (19.3)		6 (20.0)	4 (13.3)	
T2	15 (50.0)	33 (53.2)		15 (50.0)	14 (46.6)	
T3	9 (30.0)	17 (27.4)		9 (30.0)	12 (40.0)	
AJCC N staging			0.169			0.145
N0	24 (80.0)	40 (64.5)		24 (80.0)	19 (63.3)	
N1	6 (20.0)	17 (27.4)		6 (20.0)	8 (26.6)	
N2	0 (0)	5 (8.1)		0 (0)	3 (10.0)	
Perineural invasion	5 (16.6)	16 (25.8)	0.328	5 (16.6)	7 (23.3)	0.519
Lymphovascular invasion	3 (10.0)	12 (19.3)	0.255	3 (10.0)	6 (20.0)	0.278
Tumor grade						
Well	14 (46.7)	23 (37.1)	0.380	14 (46.7)	10 (33.3)	0.292
Moderate	16 (53.3)	39 (62.9)	0.380	16 (53.3)	20 (66.7)	0.292
Median number of lymph nodes harvested	12 (8–24)	13 (6–25)	0.667	12 (8–24)	14 (6–24)	0.620
Node positive	6 (20.0)	21 (33.9)	0.171	6 (20.0)	11 (36.7)	0.152
R0 resection	30 (100)	59 (95.2)	0.548	30 (100)	28 (93.3)	0.492

Values are presented as number (%) or mean (range).
LAPD, laparoscopic assisted pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy; AJCC, American Joint Committee on Cancer.

https://doi.org/10.14701/ahbps.23-144

DISCUSSION

Pancreaticoduodenectomy is one of the most complex surgical procedures primarily due to the involvement of intricate anastomosis. The most frequently encountered complication following PD is POPF, often resulting from difficulties in establishing a secure pancreatoenteric anastomosis. Even though very few institutions have adopted the minimally invasive approach for PAC there has been a notable upsurge in the utilization of minimally invasive pancreaticoduodenectomy (MIPD) over the past decade. However, MIPD continues to lag behind in popularity when compared to the laparoscopic distal pancreatectomy. TLPD is a technically challenging procedure, carrying an increased risk of complications such as POPF and bile leaks, particularly when ensuring secure completion of pancreatic and biliary anastomoses. Despite the growing interest in MIPD, a definitive learning curve for the procedure has yet to be clearly defined [21]. The concept of laparoscopic PD was initially introduced by Gagner and Pomp in 1994 [22]. After the initial case report, several studies [8,23-25] have examined the outcomes of minimally invasive approaches and highlighted their advantages, including shorter hospital stays and reduced blood loss. In the current literature, three randomized controlled trials (RCTs) have been published, with one of them, the LEOPARD-2 trial, revealing a statistically significant higher complication-related deaths that were associated with the laparoscopic approach [9,11,26]. Consequently, the study was prematurely halted, prompting the authors to advise a cautious consideration of laparoscopic PD in certain cases. Another RCT, conducted by Palanivelu et al. [11] compared laparoscopic to OPD for periampullary tumors, and was underpowered to detect differences in complication rates. It is important to note that single-layer anastomoses in pancreatojejunostomy have been identified as a risk factor for POPF in MIPD. Such anastomoses are also associated with longer operative times and a 10% higher rate of Grade B/C POPF [27].

LAPD is a hybrid surgical technique that involves laparoscopic dissection, specimen mobilization with lymphadenectomy, and extracorporeal anastomosis through a small upper midline incision. This approach leverages the advantages of laparoscopic mobilization and extracorporeal anastomosis, which can reduce the risk of anastomotic leaks. The current study compared the perioperative and pathological outcomes of LAPD and OPD. Precise patient selection plays a pivotal role in ensuring the safety and success of LAPD. Based on our initial findings, early-stage ampullary adenocarcinomas and cholangiocarcinomas are the most suitable candidates for laparoscopic procedures. Additionally, patients with early pancreatic head carcinoma, particularly those without vascular involvement and tumors measuring less than 3 cm in size, are also potential candidates for laparoscopic surgery.

In our study, LAPD proved to be safe, feasible, and equally effective as open OPD. LAPD can serve as a valuable transitional step in the learning curve toward achieving a TLPD. In this study, LAPD was associated with a longer operative time compared to OPD (463.80 ± 40.94 minutes vs. 359.00 ± 45.89 minutes, $p < 0.001$). Laparoscopic pancreatic surgery often demands more time, particularly in the initial stages of the learning curve. Similarly, other comparative studies between LAPD and OPD have shown long intraoperative time in MIPD and a high conversion rate owing to the complexity of the procedure [14,28,29]. Operative times for LAPD have been documented to vary from 342 to 512 minutes. However, with increased experience, both the duration of the procedure and blood loss have significantly decreased within the LAPD group, as observed in our study. In our study, three cases of LAPD required conversion to OPD with two cases suspicious of portal vein involvement and one case with hemorrhage during uncinate process dissection. The conversion rate to OPD ranges from 0% to 40%, with an average of 9.1% [30-33]. Tumor adhesion to the peripancreatic vascular structures and uncontrolled bleeding during uncinate dissection were the main reasons for conversion from LAPD to OPD. Several studies have highlighted the reduced intraoperative blood loss and transfusion requirements in the MIPD group, attributed to the selection of smaller tumors and improved hemostasis facilitated by magnified vision in MIPD [21]. However, our study did not show any significant difference in intraoperative blood loss. The advantages of MIPD were most evident in the postoperative phase, with consistent findings aligning with other studies. MIPD offers benefits such as early ambulation, decreased need for analgesia, rapid return of bowel function, and reduced wound complications. These advantages contribute to improved pulmonary ventilation and quicker recovery. Patients who underwent LAPD experienced a shorter incision length, reduced postoperative pain, earlier initiation of oral intake, and shorter hospital stays ($p < 0.001$).

POPF is the most frequently encountered complication following PD, with reported incidence rates ranging from 3% to 45%. In MIPD, the incidence of POPF tends to be slightly higher due to the inherent challenges of achieving precise anastomosis using laparoscopy. Dokmak et al. [34] were the first to demonstrate a significant increase in morbidity with the laparoscopic approach, particularly in a higher incidence of Grade C POPF and postoperative bleeding. They even suggested that laparoscopic PD should be considered primarily for patients at low risk for pancreatic complications. To address this concern, we included LAPD in our study, where the anastomotic technique was similar in both LAPD and OPD groups. Clinically significant Grade B POPF occurred in 19 patients, with 9 in the LAPD group and 10 in the OPD group ($p = 0.781$). No Grade C POPF was reported in either group. There were also no significant differences in the rates of PPH, with nil in the LAPD and three cases in the OPD group ($p = 0.237$). DGE is the second most common complication after PD. Some studies have reported that the incidences of postoperative ileus and

DGE are lower in MIPD compared to OPD, potentially due to the minimal manipulation of the bowel and reduced postoperative adhesions [23]. In our study, DGE was more common in OPD than LAPD, although this difference was not statistically significant (20 vs. 25, $p = 0.136$). The impact of minimally invasive surgery on the incidence of postoperative pneumonia remains unclear. Few postoperative pulmonary complications have been reported after laparoscopic surgery in the existing literature [35,36]. In our study, we reported 8 cases of postoperative pneumonia, although this difference was not statistically significant (3 cases in the LAPD group vs. 5 cases in the OPD group, $p = 0.704$). Overall, no significant differences in short-term complications were observed between the two groups. The mortality rate in previous studies varies from 1.6% to 8% [37-40]. However, in our LAPD group, no mortality occurred, which may be attributed to the low incidence of Grade B POPF. The median duration of hospitalization in the LAPD group was 8 days, falling within a lower range compared to the reported literature (typically ranging from 9 to 12 days) [40-42].

Previous meta-analyses of comparative studies have consistently demonstrated satisfactory oncologic outcomes, such as R0/R1 resection rates and lymph node yield, following LAPD compared to OPD in patients with malignant conditions [43]. In terms of oncological outcomes, our study found no statistically significant differences in tumor grade, the number of harvested lymph nodes, or margin status, which aligns with the findings of previous studies [43]. R0 resection, particularly at critical margins like the retroperitoneal margin and superior mesenteric artery margin, along with a favorable lymph nodal status, are considered the most crucial prognostic factors following PD. The incidence of R1 resection after PD for pancreatic head and periampullary malignancies has been reported to vary widely, ranging from 2% to 75% [44,45]. These discrepancies may be attributed to variations in pathological protocols and the inclusion of a diverse range of cases. Notably, previous studies on LAPD have shown a lower incidence of R1 resection, often attributed to the inclusion of patients with smaller diameters and early lesions. In our study, R0 resection was achieved in all cases within the LAPD group, whereas two cases in the OPD group resulted in R1 resection. The median number of lymph nodes harvested from the resected specimens was 12 (ranging from 8 to 24) in the LAPD group and 14 (ranging from 6 to 24) in the OPD group ($p = 0.620$). This reinforces the similarity in oncological outcomes between the two groups.

Based on the available evidence TLPD is a viable alternative for OPD but it remains a technically challenging and demanding technique that cannot be readily embraced. Our current study has demonstrated that LAPD can serve as a safe and effective bridge to overcome the learning curve necessary for TLPD. This aligns with previous reports comparing LAPD and OPD. In addition, an organized training program should remain an integral part of achieving expertise in TLPD. This program should encompass predefined milestones, planned conversion strategies, and a gradual expansion of the criteria that define eligible patient selections. Simultaneously, the implementation of an enhanced recovery protocol should run in parallel with the adoption of the LAPD approach for complex pancreatic surgeries. Both of these components are now firmly integrated into our institution's standard operating procedures. It is important to note that, since all surgeries were performed in a high-volume institution by experienced pancreatic surgeons who have already surmounted the learning curve, the results of our current study may not be generalizable to all pancreatic surgeons and low-volume centers. Selection bias is inherent to the retrospective nature of this study. Although we have made efforts to mitigate this bias through propensity score matching, the retrospective design makes it less comparable to a RCT. This being a single-center study with a relatively short follow-up period, future research should place greater emphasis on investigating long-term outcomes, including survival, recurrences, and the quality of life for patients undergoing these procedures.

Conclusion

LAPD demonstrates a favorable safety profile, technical feasibility, and short-term oncological efficacy, making it a viable option for bridging the learning curve to TLPD. This minimally invasive approach can serve as a valuable step in the process of gaining expertise about the more challenging TLPD. However, despite these promising results, there remains a significant gap in our understanding of the comprehensive advantages and limitations of LAPD. To address this knowledge gap and provide a more comprehensive evaluation of the LAPD, it is imperative to conduct an RCT that systematically compares the LAPD with OPD. These studies should consider the long-term impact on patient recovery and oncological outcomes.

FUNDING

None.

CONFLICT OF INTEREST

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

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https://doi.org/10.14701/ahbps.23-144

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Conceptualization: UA, KP. Data curation: RK, AA. Methodology: RK. Writing - original draft: BNS, KK, RK. Writing - review & editing: SY, SA.

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https://doi.org/10.14701/ahbps.23-144