Li *et al. BMC Surgery* (2024) 24:372
https://doi.org/10.1186/s12893-024-02671-1

BMC Surgery

RESEARCH

Impact of overweight on patients undergoing laparoscopic pancreaticoduodenectomy: analysis of surgical outcomes in a high-volume center

Dechao Li[1†], Shulin Wang[2†], Huating Zhang[1], Yukun Cao[3*] and Qingsen Chu[1*]

Abstract

Background The feasibility and safety of laparoscopic pancreaticoduodenectomy (LPD) in overweight patients is still controversial. This study was designed to analyze the impact of overweight on surgical outcomes in patients undergoing LPD.

Methods Data from patients who underwent LPD between January 2018 and July 2022 were analyzed retrospectively. A 1:1 propensity score-matching (PSM) analysis was performed to minimize bias between groups.

Results A total of 432 patients were enrolled, with a normal weight group ($n=241$) and an overweight group ($n=191$). After matching, 144 patients were enrolled in each group. The results showed that the incidence of clinically relevant postoperative pancreatic fistula (CR-POPF) and delayed gastric emptying (DGE) was significantly higher in the overweight group compared to the normal weight group ($P=0.036$). However, there were no significant differences in perioperative mortality (1.4% vs. 2.1%, $P=0.652$) and long-term survival outcomes between malignancy patients with different body mass index (BMI) before and after PSM (all $P>0.05$).

Conclusions It is safe and feasible for overweight patients to undergo LPD with mortality and long-term survival outcomes comparable to the normal weight group. High-quality prospective randomized controlled trials are still needed.

Keywords Body mass index, Complications, Laparoscopic pancreaticoduodenectomy, Overweight, Propensity score matching

†Dechao Li and Shulin Wang contributed equally to this work.

*Correspondence:
Yukun Cao
rainystar2002@163.com
Qingsen Chu
sanmuhaixia@163.com

[1]Department of Anesthesia, Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, Shandong 250021, China
[2]Department of Rehabilitation Medicine, The 960th Hospital of the PLA Joint Logistics Support Force, Jinan, Shandong 250031, China
[3]Department of Liver Transplantation and Hepatobiliary Surgery, Shandong Provincial Hospital Affiliated to Shandong First Medical University, Jinan, Shandong 250021, China

Introduction

Pancreaticoduodenectomy (PD) is a complex and challenging operation in general surgery, requiring extensive resection and intricate reconstruction and anastomosis techniques [1]. Additionally, postoperative complications such as pancreatic fistula, biliary leakage, abdominal infection, hemorrhage, and delayed gastric emptying (DGE) can negatively impact the prognosis [2, 3]. In recent years, laparoscopic pancreaticoduodenectomy (LPD) has gained momentum, although there have been concerns about high perioperative complications and mortality rates in the early stages of the procedure [4]. However, as minimally invasive technology advances and the level of perioperative care improves, the feasibility of LPD has gradually gained recognition [5–7].

In China, where about 30% of the population is overweight and 12% is obese, the implications of obesity for post-operative recovery are of significant concern [8]. Being overweight is considered a risk factor for various diseases, such as hypertension and diabetes [9]. Moreover, numerous studies have demonstrated that a high body mass index (BMI) is an independent risk factor for perioperative complications in patients undergoing PD [10–12]. However, there have been few studies on the effect of overweight on surgical outcomes in patients undergoing LPD [8, 13].

In this study, we conducted a retrospective propensity score matching (PSM) analysis of data from patients who underwent LPD based on a high-volume center to assess the impact of overweight on surgical outcomes, and long-term survival outcomes for patients undergoing LPD.

Materials and methods

Study design and variables

A retrospective study was conducted at Shandong Provincial Hospital between January 2018 and July 2022, focusing on patients undergoing LPD. This study was approved by the Medical Ethics Committee of Shandong Provincial Hospital (No.2022 − 178), and all patients gave informed consent and signed written informed consent. Different from the classification for BMI used by the World Health Organization (WHO), the cutoffs for Chinese have slight alterations because of the underestimated obesity risk according to Cooperative Meta-analysis Group of China Obesity Task Force [14]. The patients were categorized into two groups based on their BMI: the normal weight group ($18.5 < BMI \leq 24$ kg/m^2) and the overweight group ($BMI > 24$ kg/m^2). Furthermore, the overweight group was further divided into a non-obese subgroup ($24 < BMI \leq 28$ kg/m2) and an obese subgroup ($BMI > 28$ kg/m^2).

The preoperative data collected included age, gender, BMI, American Association of Anesthesiologists (ASA) classification, medical history (including malignant tumors, chronic diseases such as hypertension and diabetes, smoking, and alcohol consumption), and serological tests (routine blood test, liver function, and tumor markers). Intraoperative data such as operative duration and bleeding volume were also recorded. Postoperative data included the length of hospital stay (LOS), complications (such as pancreatic fistula, biliary leakage, intra-abdominal infection, DGE, etc.).

Surgical procedures

During the LPD procedure, the Kocher incision is routinely used, and only when the pancreatic head tumor is extensively invaded by surrounding tissue, or when the second and third segments of the duodenum are tightly attached to the posterior tissue, the Kocher incision combined with the reverse Kocher incision is used. The stomach is cut from the greater curvature to the lesser curvature of the stomach, and the opening at the corner of the greater curvature is left for the gastrojejunostomy. The common hepatic duct is traversed, just above the point where the cystic duct joins the common bile duct, and the proximal end is temporarily clipped with a laparoscopic vascular clamp for hepaticojejunostomy. For pancreatic head cancer cases, the uncinate procedure is fully resected and mesopancreatic excision (MPE) is conventional performed according to the criteria [15–17]. The level 2–3 resection with periadventitial dissection including the nerve plexus along the right side of the SMA is always necessary to achieve a negative margin and improve curability [15–18]. For both duodenal and ampullary tumors, extended lymph node dissection was not performed and the mesentery of the uncinate process was dissected along the right edge of the superior mesentery artery (SMA). Pancreatic duct stents are used in pancreaticojejunostomy [19]. A modified parachute suturing technique is used in hepaticojejunostomy [20]. An endoscopic stapler is used to perform gastrojejunostomy. Detailed surgical procedures and related surgical videos can be found in our previous published papers and supplementary videos [6, 7, 20]. We fully informed patients about the pros and cons of LPD and OPD before the procedure. Whether patients accept LPD is a matter of their own consideration and willingness, and they have signed the relevant informed consent form for the procedure.

Inclusion and exclusion criteria

Patients were included if they met the following criteria: (1) being over 18 years old; (2) patients with benign, premalignant, resectable malignant or borderline resectable tumors of the pancreatic and periampullary region; (3) complete clinical and follow-up data; (4) underwent curative LPD surgery; (5) ASA scores of I-III without severe heart, lung, kidney, or other organ dysfunction.

Patients were excluded if they met any of the following criteria: (1) had distant metastasis, (2) with a history of other malignant tumors, (3) with BMI < 18.5 kg/m², or (4) data missing or lost to follow-up.

Definitions

Surgical complications were assessed using the Clavien-Dindo classification, with major complications defined as Clavien-Dindo grade III or higher [21]. Postoperative pancreatic fistula (POPF), DGE, and postoperative hemorrhage (PPH) were defined and graded according to the criteria set by the International Study Group of Pancreatic Surgery (ISGPS) [22, 23]. Grade B and C postoperative pancreatic fistulas were considered clinically relevant postoperative pancreatic fistula (CR-POPF) [24]. Bile leakage was defined according to the criteria set by the International Study Group of Liver Surgery (ISGLS) [22], and all bile leakage were enrolled. In the context, resection margins were considered negative (R0) when no tumor was evident along the transection surface which including circumferential resection margin (CRM)+ (0 mm < CRM of ≤1 mm) and CRM- (CRM of >1 mm) [25, 26].

Followup

After surgery, patients were followed every three months until death or loss of follow-up. The follow-up examinations included serum tests (blood routine, liver function, etc.), abdominal B-ultrasound, and contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI). Perioperative death was defined as death occurring within one month of surgery. The final follow-up date was set for July 2023.

Statistical analysis

Continuous variables with a normal distribution were expressed as mean ± standard (SD) and tested using the student's t-test. Variables that did not conform to the normal distribution were expressed as median (interquartile range, IQR) and tested using the Mann-Whitney U test. Categorical variables were expressed as frequencies (%) and compared using the Chi-squared test or Fisher exact test. The survival curves were plotted using the Kaplan-Meier method and the differences in survival between groups were compared using a log-rank test.

A 1:1 PSM with a caliper of 0.1 was performed using nearest neighbor matching to minimize differences in baseline characteristics between normal weight and overweight groups. The results of the balance test were displayed using a histogram of standardized differences and a dot plot of standardized mean differences. All tests were two-tailed, and a significance level of *P* value < 0.05 was considered statistically significant. Data analysis was performed using SPSS statistical software (version 26.0, IBM, Armonk, NY, USA) and R program (version 4.1.2, R Foundation for Statistical Computing, Vienna, Austria) with the MatchIt package.

Results

Baseline characteristics

Of the 432 patients included in this study (Fig. 1), 241 were in the normal weight group with a median BMI of 21.9 (20.6–23.0) kg/m², and 191 were in the overweight group with a BMI of 26.3 (25.0-27.8) kg/m². Prior to PSM, the overweight group had higher rates of high blood pressure (34.6% vs. 24.1%, *P* = 0.017), preoperative albumin (38.8 vs. 38.0 g/L, *P* = 0.021), and preoperative hemoglobin (128 vs. 123 g/L, *P* = 0.039) values. After a 1:1 PSM, each group enrolled 144 patients with a median BMI of 21.5 (20.5–23.1) kg/m² in the normal weight group, and 26.1 (25.1–27.7) kg/m² in the overweight group (*P* < 0.001), ensuring that the differences between the groups were balanced (Table 1).

Perioperative outcomes

The surgical outcomes of patients undergoing LPD after PSM are presented in Table 2. Following PSM, the incidence of CR-POPF was lower in normal weight group compared to overweight group (13.9% vs. 25.7%; *P* = 0.042). Additionally, the occurrence of DGE was also lower in normal weight group compared to overweight group (11.1% vs. 21.5%; *P* = 0.017). However, there were no significant differences in the operative time, intraoperative hemorrhage, lymph node harvest, postoperative LOS, proportion of intraoperative blood transfusion, R0 resection rate, lymph node metastasis, bile leakage, gastrointestinal fistula, severe complications, reoperation, and 30-day mortality between the two groups (all *P* > 0.05).

Subgroup analysis of overweight patients demonstrated that there was no significant difference in the probability of CR-POPF and DGE between the non-obese group and the obese group (both *P* > 0.05) (Table 3). Additionally, we further added subgroup analysis of normal weight and obese patients, and the results showed that compared with normal weight patients, patients in the obese group had longer operation time (305.0 min vs. 330.0 min, *P* = 0.029) and more intraoperative blood loss (100.0 ml vs. 200.0 min, *P* < 0.001), although there was no statistically significant difference in postoperative complication rate and postoperative hospital stay between the two groups. (Supplementary Table 1)

Long-term survival analysis

Following PSM, there was also no statistically significant difference in long-term survival outcomes between malignancy patients with different BMI before and after PSM (all *P* > 0.05). The detailed overall survival (OS) and

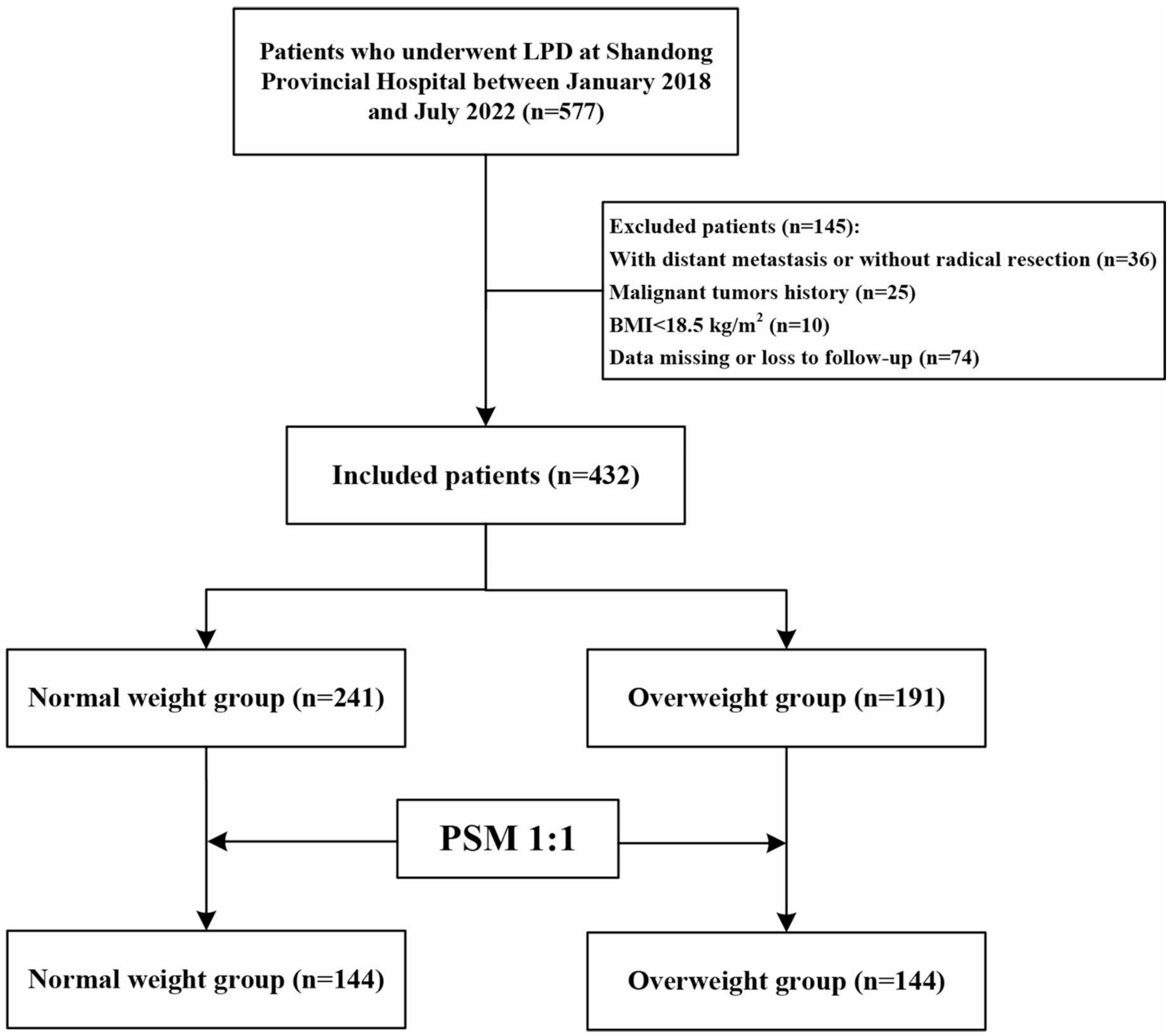

Fig. 1 Flow chart of the study-population screening

disease-free survival (DFS) outcomes for normal-weight and overweight patients with pancreatic ductal adenocarcinoma, distal cholangiocarcinoma, ampullary and duodenal carcinoma are shown in Fig. 2 and supplementary Tables 2–3.

Discussion

Due to the development of surgical procedures and advances in post-operative treatment and care, the postoperative mortality for LPD has been consistently lower than 5% in certain major medical facilities and is not significantly different from that of OPD [27, 28]. Despite the benefits of reduced surgical trauma and rapid post-operative recovery provided by LPD, the incidence of postoperative complications remains high, adversely affecting the outcome of patients undergoing LPD [29].

Overweight and obesity are now recognized as chronic disorders that increase the risk of many different diseases, and poor outcomes following major surgery [30, 31]. High BMI has been linked to a number of intraoperative or postoperative adverse events, including difficulty in lymph node dissection, increased intraoperative blood loss, and the incidence of postoperative pancreatic fistula [13]. However, some studies contradict this conclusion [32–34]. Therefore, in the present study, we aimed to assess the impact of overweight and surgical outcomes, as well as the long- term survival outcomes of patients undergoing LPD.

Obese patients are more challenging to operate on. According to the study findings, there was a significant difference between the normal weight and obese groups in terms of median operative time, intraoperative blood loss, but not postoperative LOS. We analyze that LPD reduces the amount of time it takes to open and close the abdomen, while also causing less trauma to the patient. Fat accumulation severely affects the surgical visual field and intraoperative exposure, which affects the amount of lymph nodes and nerve plexus removed during surgery.

Table 1 The baseline characteristics of patients in normal weight group and overweight group who underwent LPD before and after PSM

Variables	Before PSM			After PSM		
	Normal weight (*n* = 241)	Overweight (*n* = 191)	*P* value	Normal weight (*n* = 144)	Overweight (*n* = 144)	*P* value
Age, year	63.0 (53.0–68.0)	62.0 (53.5–67.0)	0.646	63.0 (55.0–68.0)	61.5 (54.0–67.0)	0.546
Sex, male	151 (62.7%)	122 (63.9%)	0.794	98 (68.1%)	89 (61.8%)	0.266
ASA grade ≤ II	179 (74.3%)	140 (73.3%)	0.819	112 (77.8%)	109 (75.7%)	0.676
Preoperative biliary drainage	35 (14.5%)	25 (13.1%)	0.669	15 (10.4%)	20 (13.9%)	0.367
Biliary infection	40 (16.6%)	30 (15.7%)	0.803	20 (13.9%)	25 (17.4%)	0.417
Hypertension	58 (24.1%)	66 (34.6%)	**0.017**	42 (29.2%)	40 (27.8%)	0.794
Diabetes	48 (19.9%)	31 (16.2%)	0.325	22 (15.3%)	23 (16%)	0.871
Smoking, year						
< 10	38 (15.8%)	28 (14.7%)	0.684	26 (18.1%)	25 (17.4%)	0.859
≥ 10	43 (17.8%)	29 (15.2%)		24 (16.7%)	21 (14.6%)	
Drinking, year						
< 10	35 (14.5%)	25 (13.1%)	0.608	23 (16.0%)	18 (12.5%)	0.691
≥ 10	37 (15.4%)	36 (18.8%)		26 (18.1%)	26 (18.1%)	
Abdominal surgery history	1 (0.4%)	2 (1.0%)	0.432	1 (0.7%)	2 (1.4%)	0.562
ALB, g/L	38.0 (34.7–41.2)	38.8 (35.9–41.95)	**0.021**	38.5 (35.4–41.4)	38.9 (35.8–41.6)	0.656
TBIL, umol/L	57.8 (15.5- 192.4)	67.6 (16.0- 237.4)	0.375	68.2 (15.7- 216.2)	51.9 (15.9- 218.7)	0.932
Hb, g/L	123 (112–136)	128 (118–138)	**0.039**	128 (114–140)	128 (117–137)	0.944
WBC, 10^9 /L	5.8 (4.6–7.6)	5.6 (4.6–7.2)	0.389	5.9 (4.7–7.3)	5.7 (4.6–7.6)	1.000
CA19-9, U/ml	49.9 (13.9- 191.1)	56.4 (16.7- 210.5)	0.278	54.7 (14.7- 190.1)	54.4 (16.5- 184.8)	0.544
Neo-adjuvant therapy	6 (2.5%)	5 (2.6%)	0.933	6 (4.2%)	4 (2.8%)	0.520
Adjuvant therapy	122 (50.6%)	90 (47.1%)	0.470	76 (52.8%)	71 (49.3%)	0.556
Pathological diagnosis						
PDAC	58 (24.1%)	36 (18.8%)	0.733	34 (23.6%)	30 (20.8%)	0.596
DCC	66 (27.4%)	52 (27.2%)		32 (22.2%)	42 (29.2%)	
AMP&D	70 (29.0%)	58 (30.4%)		37 (25.7%)	32 (22.2%)	
NET	5 (2.1%)	4 (2.1%)		5 (3.5%)	2 (1.4%)	
IPMN	5 (2.1%)	3 (1.6%)		4 (2.8%)	3 (2.1%)	
SPT	4 (1.7%)	2 (1.0%)		3 (2.1%)	1 (0.7%)	
Others	33 (13.7%)	36 (18.8%)		29 (20.1%)	34 (23.6%)	
TNM staging (8th) for malignancy	196	149		103	105	
0-I	21 (10.7%)	15 (10.1%)	0.980	12 (11.7%)	11 (10.5%)	0.688
II	144 (73.5%)	110 (73.8%)		68 (66.0%)	75 (71.4%)	
III	31 (15.8%)	24 (16.1%)		23 (22.3%)	19 (18.1%)	

Data are presented as N (%) or median (IQR), Bold text indicated that these variables were statistically significant

LPD, laparoscopic pancreaticoduodenectomy; PSM, propensity score matching; BMI, Body Mass Index; ASA, American Society of Anesthesiologists; ALB, albumin; TBIL, total bilirubin; Hb, hemoglobin; WBC, white blood cell; CA19-9, carbohydrate antigen19-9; PDAC, pancreatic ductal adenocarcinoma; DCC, distal cholangiocarcinoma; AMP&D, ampullary and duodenal carcinoma; NET, neuroendocrine tumor; IPMN, intraductal papillary mucous neoplasm; SPT, solid pseudopapillary tumor

As a result, level 2 or 3 MPE can be more difficult in obese patients. However, there was no significant difference in lymph node harvest ($P = 0.192$) between the normal and the overweight groups. In addition, the survival analysis showed no statistically significant difference in long-term survival outcomes between normal-weight and overweight malignancy patients. We analyze that this may be due to the fact that all surgeons in the current study have passed the learning curve of LPD [6, 7], which further demonstrated that after the learning curve, MPE is technically competent in these patients. Nonetheless, further studies and validation are necessary to determine whether increased BMI affects the number of lymph nodes dissected and the long-term survival outcomes in patients undergoing LPD.

The incidence of postoperative complications following LPD remains high. Pancreatic fistula is the primary complication of LPD, accounting for approximately 14–50% [35]. According to previous studies, patients with a high BMI have a softer texture of the pancreas and a higher incidence of postoperative pancreatic fistula [36, 37]. Similar to previous studies, this study also found that a high BMI was significantly associated with CR-POPF risk [32, 38–40]. However, no significant differences in pancreatic texture and pancreatic duct diameter were observed in this study. This lack of difference may be

Table 2 The surgical outcomes of patients underwent LPD after PSM

Variables	Normal weight (*n* = 144)	Overweight (*n* = 144)	*P* value
Operative time, min	305.0 (274.0-367.5)	325.0 (280.0-400.0)	0.871
Intraoperative hemorrhage, ml	100.0 (50.0- 200.0)	150.0 (100.0- 250.0)	0.439
Blood transfusion	14 (9.7%)	18 (12.5%)	0.453
Pancreatic texture			
Hard and tough	35 (24.3%)	31 (21.5%)	0.613
Soft and moderate	86 (59.7%)	94 (65.3%)	
Unavailable	23 (16.0%)	19 (13.2%)	
Wirsung duct diameter			
< 3 mm	86 (59.7%)	80 (55.6%)	0.491
≥ 3 mm	37 (25.7%)	46 (31.9%)	
Unavailable	21 (14.6%)	18 (12.5%)	
R0 resection	129 (89.6%)	125 (86.8%)	0.465
Malignant tumor	103 (71.5%)	105 (72.9%)	0.792
Lymph node harvest	14.5 (12.0–18.0)	15.0 (12.0–17.0)	0.192
Lymph node metastasis	31 (22.6%)	30 (21.9%)	0.885
Vascular involvement	13 (9.0%)	12 (8.3%)	0.834
Postoperative LOS, day	13.5 (10.0–18.0)	13.5 (10.0–19.0)	0.452
Postoperative hemorrhage	9 (6.2%)	17 (11.9%)	0.096
CR-POPF			
B	14 (9.7%)	26 (18.1%)	**0.042**
C	6 (4.2%)	11 (7.6%)	
Bile leakage	17 (11.8%)	18 (12.5%)	0.857
DGE	16 (11.1%)	31 (21.5%)	**0.017**
B	7 (4.9%)	17 (11.8%)	
C	5 (3.5%)	8 (5.6%)	
Gastrointestinal fistula	1 (0.7%)	5 (3.5%)	0.216
Clavien-Dindo grade ≥ III	32 (22.2%)	38 (26.4%)	0.410
Reoperation	5 (3.5%)	7 (4.9%)	0.555
30-day mortality	2 (1.4%)	3 (2.1%)	0.652

Data are presented as (%) or median (IQR), Bold text indicated that these variables were statistically significant

LPD, laparoscopic pancreaticoduodenectomy; PSM, propensity score matching; LOS, length of stay; CR-POPF, clinically relevant-postoperative pancreatic fistula; DGE, Delayed gastric emptying

Table 3 Subgroup analysis of surgical results of overweight patients underwent LPD after PSM

Variables	Non-obese (*n* = 113)	Obese (*n* = 31)	*P* value
Operative time, min	315.0 (270.0, 430.0)	330.0 (285.0, 435.0)	0.392
Intraoperative hemorrhage, ml	150.0 (100.0, 250.0)	200 (100.0, 250.0)	0.326
Blood transfusion	13 (11.5%)	5 (16.1%)	0.502
Pancreatic texture			
Hard and tough	24 (21.2%)	7 (22.6%)	0.454
Soft and moderate	72 (63.7%)	22 (71.0%)	
Unavailable	17 (15.0%)	2 (6.5%)	
Wirsung duct diameter			
< 3 mm	64 (56.6%)	16 (51.6%)	0.427
≥ 3 mm	37 (32.7%)	9 (29.0%)	
Unavailable	12 (10.6%)	6 (19.4%)	
Malignant tumor	81 (71.7%)	24 (77.4%)	0.524
Lymph node harvest	14.5 (12.0, 18.0)	14.0 (12.5, 18.0)	0.184
Lymph node metastasis	24 (22.4%)	6 (20%)	0.776
Vascular involvement	8 (7.1%)	4 (12.9%)	0.501
Postoperative LOS, day	13.0 (10.0, 20.0)	13.0 (11.0, 18.0)	0.750
Postoperative hemorrhage	14 (12.4%)	3 (9.7%)	0.920
CR-POPF			
B	20 (17.7%)	6 (19.4%)	0.945
C	9 (8.0%)	2 (6.5%)	
Bile leakage	16 (14.2%)	2 (6.5%)	0.399
DGE	26 (23%)	5 (16.1%)	0.409
Gastrointestinal fistula	4 (3.5%)	1 (3.2%)	1.000
Clavien-Dindo grade ≥III	30 (26.5%)	8 (25.8%)	0.934
Reoperation	5 (4.4%)	2 (6.5%)	0.642
30-day mortality	2 (1.8%)	1 (3.2%)	0.520

Data are presented as (%) or median (IQR), Bold text indicated that these variables were statistically significant. LPD, laparoscopic pancreaticoduodenectomy; PSM, propensity score matching; BMI, Body Mass Index; LOS, length of stay; CR-POPF, clinically relevant-postoperative pancreatic fistula; DGE, Delayed gastric emptying

attributed to the limited data available, as laparoscopic surgery only allows exploration of the texture of the pancreas and the diameter of the pancreatic ducts using instruments that are not in direct contact.

Previous studies on the relationship between DGE and overweight have yielded inconsistent results. Chen and Sfarti et al. found that patients with high BMI had a higher incidence of DGE [41, 42]. However, a retrospective study conducted at a single institution did not find a significant association between obesity and DGE [43]. In this study, high BMI was found to be associated with DGE after LPD. It seems plausible that the association between BMI and DGE could be an effect of increased rates of pancreatic fistula or deep/organ space infection secondary to increased visceral adiposity, rather than an independent effect [44]. Of course, these conflicting findings point to the need for further investigation into the underlying reasons behind the effect of BMI on DGE.

For these patients, carefully intraoperative manipulation, and appropriate drain management are particularly important [45]. Relevant studies have shown that for patients at high risk of CR-POPF, active review of abdominal ultrasound, CT and other measures to determine whether there is effusion, appropriate anti-infective treatment, nutritional support and abdominal irrigation are helpful for patients' recovery [45–47]. Besides, acupuncture and moxibustion therapy of traditional Chinese medicine also plays a positive role in promoting the recovery of DGE [48], which are also commonly used in our management. In addition, studies have revealed that food intake does not aggravate POPF and does not prolong the length of drain placement or hospital stay after

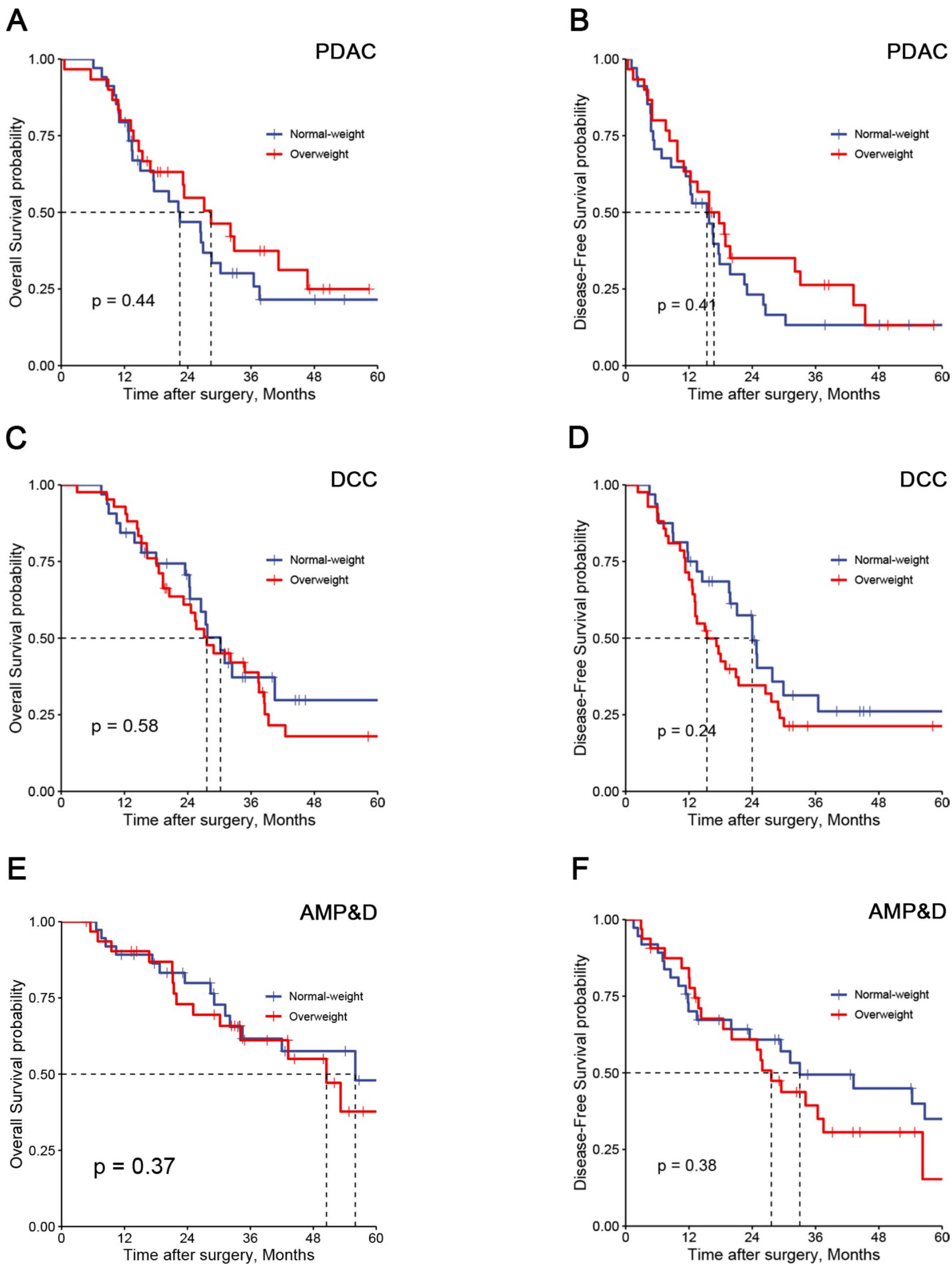

Fig. 2 OS and DFS for normal-weight and overweight patients with PDAC, DCC, and AMP&D. (A-B, OS and DFS for normal-weight and overweight patients with PDAC; C-D, OS and DFS for normal-weight and overweight patients with DCC; E-F, OS and DFS for normal-weight and overweight patients with AMP&D.) (OS, overall survival; DFS, disease-free survival; PDAC, pancreatic ductal adenocarcinoma; DCC, distal cholangiocarcinoma; AMP&D, ampullary and duodenal carcinoma)

PD. Thus, there is no need to avoid oral dietary intake in patients with POPF [49].

In addition, we performed a subgroup analysis of patients who were overweight. The results demonstrated that there were no significant differences between non-obese and obese individuals in terms of intra-operative conditions and postoperative complications. This observation may be attributed to the low prevalence of obesity among the patients in the present study. Excess obesity could potentially encourage surgeons to opt for an open approach, resulting in a limited number of obese patients undergoing the procedure. Therefore, further investigations with larger sample sizes are required for the analysis of patients with extremely high BMI or obesity after LPD.

There was no significant difference in perioperative mortality and long-term survival outcomes between the normal weight group and the overweight group. This may be due to advances in surgical techniques and improved post-operative management in high-volume centers, which compensate for the adverse effects of overweight on LPD outcomes. For all this, advances in diagnostic approaches, perioperative management, radiotherapy techniques, and systemic therapies for advanced disease have made relevant but only modest incremental progress in patient outcomes over the past decade [50, 51]. In the study, PDAC had a 5-year survival rate of 21.5 to 25.0% and a median survival time of 22.5 to 28.4 months. The 5-year survival rate for DCC was 18.0 to 29.8%, with a median survival time of 27.6 to 30.2 months. The unsatisfactory survival of PDAC and DCC patients in this study may be due to the fact that nearly half of the patients did not receive postoperative adjuvant therapy or did not receive an adequate course of adjuvant therapy. Therefore, there is still a need for enhanced education on adjuvant therapy and active multidisciplinary treatment during follow-up.

Additionally, previous studies have shown that postoperative complications can delay patients from receiving further adjuvant therapy, which may affect patients' long-term prognosis [52, 53]. Although our survival analysis results showed that there was no significant statistical difference in the long-term prognosis of malignancy patients with different weight groups, weight control may also have a more positive significance in reducing the occurrence of postoperative complications and even improving the long-term prognosis of patients, which of course needs further research.

There are several limitations to this study. Firstly, the "overweight" cohort included obese patients with a BMI of at least 28 kg/m^2. The representation of obese patients in the general population is insufficient to construct a sufficiently large cohort of obese patients. Second, while we have had in-depth communication with the pathology department of the hospital, it is unfortunately not possible to provide accurate CRM+and CRM-ratios at this time. In the future, we hope to take this opportunity to standardize our pathological description and diagnosis. In addition, this study was performed retrospectively. Although a 1:1 PSM was performed to minimize baseline differences between groups, selection bias was inevitable. Finally, this study was conducted at a single center, necessitating validation of the results through multi-center and large-sample clinical studies.

Conclusions

In conclusion, it is safe and feasible for overweight patients to undergo LPD. There were no significant differences in perioperative mortality and long-term survival outcomes between the overweight and normal weight groups of patients. High-quality prospective randomized controlled trials are still needed.

Abbreviations

LPD	Laparoscopic pancreaticoduodenectomy
PSM	Propensity score-matching
EBL	Estimated blood loss
CR-POPF	Clinically relevant postoperative pancreatic fistula
DGE	Delayed gastric emptying
PD	Pancreaticoduodenectomy
BMI	Body mass index
WHO	World Health Organization
ASA	American Association of Anesthesiologists
POPF	Postoperative pancreatic fistula
LOS	Length of stay
PPH	Post-pancreatectomy hemorrhage
ISGPS	International Study Group of Pancreatic Surgery
ISGLS	International Study Group of Pancreatic Surgery
CRM	Circumferential resection margin
MPE	Mesopancreatic excision
CT	Computed tomography
MRI	Magnetic resonance imaging
SD	Standard deviation
IQR	Interquartile range
ALB	Albumin
CA19-9	Carbohydrate antigen 19 – 9
TBIL	Total bilirubin
Hb	Hemoglobin
WBC	White blood cell

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-024-02671-1.

Supplementary Material 1

Acknowledgements

We would like to thank all the authors for their hard work on this article.

Author contributions

Dechao Li: project development, data analysis and collection, manuscript writing; Shulin Wang: project development, data analysis, manuscript editing; Huating Zhang: data analysis, manuscript editing; Yukun Cao: project development, manuscript editing, financial support; Qingsen Chu: project development, manuscript editing, financial support.

Funding
This study was supported by Natural Science Foundation of Shandong Province (ZR2023QH287).

Data availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Medical Ethics Committee of Shandong Provincial Hospital (No.2022 – 178). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all patients.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 19 May 2024 / Accepted: 12 November 2024
Published online: 22 November 2024

References

1. Warshaw AL, Thayer SP. Pancreaticoduodenectomy. J Gastrointest Surg. 2004;8(6):733–41.
2. Cameron JL, He J. Two thousand consecutive pancreaticoduodenectomies. J Am Coll Surg. 2015;220(4):530–6.
3. Simon R. Complications after Pancreaticoduodenectomy. Surg Clin North Am. 2021;101(5):865–74.
4. Asbun HJ, Stauffer JA. Laparoscopic vs open pancreaticoduodenectomy: overall outcomes and severity of complications using the Accordion Severity Grading System. J Am Coll Surg. 2012;215(6):810–9.
5. Cameron JL, Riall TS, Coleman J, Belcher KA. One thousand consecutive pancreaticoduodenectomies. Ann Surg. 2006;244(1):10–5.
6. Wang M, Li D, Chen R, Huang X, Li J, Liu Y, Liu J, Cheng W, Chen X, Zhao W, et al. Laparoscopic versus open pancreatoduodenectomy for pancreatic or periampullary tumours: a multicentre, open-label, randomised controlled trial. Lancet Gastroenterol Hepatol. 2021;6(6):438–47.
7. Zhang X-P, Xu S, Zhao Z-M, Yu G-S, Han B, Chen X, Ma Y-T, Xu Z-Z, Liu Z, Li E-S, et al. Outcomes of robotic Versus Laparoscopic Pancreatoduodenectomy following Learning curves of surgeons: a Multicenter Study on 2255 patients. Annals of Surgery; 2023.
8. Wang X, Liang X, Wang S, Zhang CS. The impact of body Mass Index on multiple complications, respiratory complications, failure to rescue and In-hospital mortality after laparoscopic pancreaticoduodenectomy: a single-Center Retrospective Study. J Laparoendoscopic Adv Surg Techniques Part A 2024.
9. Abar L, Vieira AR, Aune D, Sobiecki JG, Vingeliene S, Polemiti E, Stevens C, Greenwood DC, Chan DSM, Schlesinger S, et al. Height and body fatness and colorectal cancer risk: an update of the WCRF-AICR systematic review of published prospective studies. Eur J Nutr. 2018;57(5):1701–20.
10. Tang T, Tan Y, Xiao B, Zu G, An Y, Zhang Y, Chen W, Chen X. Influence of body Mass Index on Perioperative outcomes following pancreaticoduodenectomy. J Laparoendosc Adv Surg Tech A. 2021;31(9):999–1005.
11. Han SH, Kang CM, Hwang HK, Yoon DS, Lee WJ. The Yonsei experience of 104 laparoscopic pancreaticoduodenectomies: a propensity score-matched analysis with open pancreaticoduodenectomy. Surg Endosc. 2020;34(4):1658–64.
12. Mathur A, Luberice K, Paul H, Franka C, Rosemurgy A. Increasing body mass index portends abbreviated survival following pancreatoduodenectomy for pancreatic adenocarcinoma. Am J Surg. 2015;209(6):969–73.
13. Wang H, Jin J, Zhu F, Peng F, Wang M, Qin R. The ratio of abdominal depth to body mass index is a preoperative predictor of postoperative complications after laparoscopic pancreaticoduodenectomy: a retrospective propensity score matched analysis. Surg Endosc. 2021;35(12):6472–80.
14. Force CM-aGoCOT. Predictive values of body mass index and waist circumference to risk factors of related diseases in Chinese adult population. Chin J Epidemiol 2002(01):10–5.
15. Wellner UF, Krauss T, Csanadi A, Lapshyn H, Bolm L, Timme S, Kulemann B, Hoeppner J, Kuesters S, Seifert G, et al. Mesopancreatic stromal clearance defines curative resection of pancreatic Head Cancer and can be predicted preoperatively by radiologic parameters: a retrospective study. Medicine. 2016;95(3):e2529.
16. Safi SA, Haeberle L, Fluegen G, Lehwald-Tywuschik N, Krieg A, Keitel V, Luedde T, Esposito I, Rehders A, Knoefel WT. Mesopancreatic excision for pancreatic ductal adenocarcinoma improves local disease control and survival. Pancreatology: Official J Int Association Pancreatology (IAP) [et Al]. 2021;21(4):787–95.
17. Inoue Y, Saiura A, Oba A, Kawakatsu S, Ono Y, Sato T, Mise Y, Ishizawa T, Takahashi Y, Ito H. Optimal extent of Superior Mesenteric Artery Dissection during Pancreaticoduodenectomy for Pancreatic Cancer: Balancing Surgical and Oncological Safety. J Gastrointest Surgery: Official J Soc Surg Aliment Tract. 2019;23(7):1373–83.
18. Safi S-A, Haeberle L, Rehders A, Fung S, Vaghiri S, Roderburg C, Luedde T, Ziayee F, Esposito I, Fluegen G et al. Neoadjuvant Treatment lowers the risk of Mesopancreatic Fat Infiltration and Local Recurrence in patients with pancreatic Cancer. Cancers. 2021;14(1).
19. Hong D, Li H, Liu X, Jiang P, Yu G, Liu X, Liu J, Liu Y, Liu J, Lau WY. Incidence of postoperative pancreatic fistula after using a defined pancreaticojejunostomy technique for laparoscopic pancreaticoduodenectomy: a prospective multicenter study on 1033 patients. Int J Surg (London England). 2022;101:106620.
20. Li G, Yuan L, Yu G, Xu Y, Liu J. A modified suture technique in Hepaticojejunostomy. Med Sci Monitor: Int Med J Experimental Clin Res. 2020;26:e921896.
21. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, de Santibañes E, Pekolj J, Slankamenac K, Bassi C, et al. The Clavien-Dindo classification of surgical complications: five-year experience. Ann Surg. 2009;250(2):187–96.
22. Bassi C, Marchegiani G, Dervenis C, Sarr M, Abu Hilal M, Adham M, Allen P, Andersson R, Asbun HJ, Besselink MG, et al. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery. 2017;161(3):584–91.
23. Wente MN, Bassi C, Dervenis C, Fingerhut A, Gouma DJ, Izbicki JR, Neoptolemos JP, Padbury RT, Sarr MG, Traverso LW, et al. Delayed gastric emptying (DGE) after pancreatic surgery: a suggested definition by the International Study Group of pancreatic surgery (ISGPS). Surgery. 2007;142(5):761–8.
24. Akiba J, Nakashima O, Hattori S, Tanikawa K, Takenaka M, Nakayama M, Kondo R, Nomura Y, Koura K, Ueda K, et al. Clinicopathologic analysis of combined hepatocellular-cholangiocarcinoma according to the latest WHO classification. Am J Surg Pathol. 2013;37(4):496–505.
25. Wittekind C, Compton C, Quirke P, Nagtegaal I, Merkel S, Hermanek P, Sobin LH. A uniform residual tumor (R) classification: integration of the R classification and the circumferential margin status. Cancer. 2009;115(15):3483–8.
26. Chen K, Liu X-L, Pan Y, Maher H, Wang X-F. Expanding laparoscopic pancreaticoduodenectomy to pancreatic-head and periampullary malignancy: major findings based on systematic review and meta-analysis. BMC Gastroenterol. 2018;18(1):102.
27. Torphy RJ, Friedman C, Halpern A, Chapman BC, Ahrendt SS, McCarter MM, Edil BH, Schulick RD, Gleisner A. Comparing short-term and oncologic outcomes of minimally invasive Versus Open Pancreaticoduodenectomy Across Low and high volume centers. Ann Surg. 2019;270(6):1147–55.
28. Poves I, Burdío F, Morató O, Iglesias M, Radosevic A, Ilzarbe L, Visa L, Grande L. Comparison of Perioperative outcomes between Laparoscopic and Open Approach for Pancreatoduodenectomy: the PADULAP Randomized Controlled Trial. Ann Surg. 2018;268(5):731–9.
29. Wang X, Cai Y, Jiang J, Peng B. Laparoscopic pancreaticoduodenectomy: outcomes and experience of 550 patients in a single Institution. Ann Surg Oncol. 2020;27(11):4562–73.
30. Global BMIMC, Di Angelantonio E, Bhupathiraju Sh N, Wormser D, Gao P, Kaptoge S, Berrington de Gonzalez A, Cairns BJ, Huxley R, Jackson Ch L, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet. 2016;388(10046):776–86.
31. Robinson JR, Carroll RJ, Bastarache L, Chen Q, Mou Z, Wei WQ, Connolly JJ, Mentch F, Sleiman P, Crane PK, et al. Association of Genetic Risk of Obesity with postoperative complications using mendelian randomization. World J Surg. 2020;44(1):84–94.

32. Zhang JY, Huang J, Zhao SY, Liu X, Xiong ZC, Yang ZY. Risk factors and a New Prediction Model for Pancreatic Fistula after Pancreaticoduodenectomy. Risk Manag Healthc Policy. 2021;14:1897–906.
33. Shimizu A, Tani M, Kawai M, Hirono S, Miyazawa M, Uchiyama K, Yamaue H. Influence of visceral obesity for postoperative pulmonary complications after pancreaticoduodenectomy. J Gastrointest Surg. 2011;15(8):1401–10.
34. Le Zarzavadjian A, Fuks D, Montali F, Cesaretti M, Costi R, Wind P, Smadja C, Gayet B. Predicting the Severity of Pancreatic Fistula after Pancreaticoduodenectomy: overweight and blood loss as independent risk factors: retrospective analysis of 277 patients. Surg Infect (Larchmt). 2019;20(6):486–91.
35. Shrikhande SV, D'Souza MA. Pancreatic fistula after pancreatectomy: evolving definitions, preventive strategies and modern management. World J Gastroenterol. 2008;14(38):5789–96.
36. Hu BY, Wan T, Zhang WZ, Dong JH. Risk factors for postoperative pancreatic fistula: analysis of 539 successive cases of pancreaticoduodenectomy. World J Gastroenterol. 2016;22(34):7797–805.
37. Rosso E, Casnedi S, Pessaux P, Oussoultzoglou E, Panaro F, Mahfud M, Jaeck D, Bachellier P. The role of fatty pancreas and of BMI in the occurrence of pancreatic fistula after pancreaticoduodenectomy. J Gastrointest Surg. 2009;13(10):1845–51.
38. El Nakeeb A, Hamed H, Shehta A, Askr W, El Dosoky M, Said R, Abdallah T. Impact of obesity on surgical outcomes post-pancreaticoduodenectomy: a case-control study. Int J Surg. 2014;12(5):488–93.
39. Shamali A, Shelat V, Jaber B, Wardak A, Ahmed M, Fontana M, Armstrong T, Abu Hilal M. Impact of obesity on short and long term results following a pancreatico-duodenectomy. Int J Surg. 2017;42:191–6.
40. Chen G, Zheng Z, Yi H, Yue Q, Li L. An analysis of risk factors for clinically relevant pancreatic fistulas after laparoscopic pancreaticoduodenectomy. Medicine. 2023;102(20):e33759.
41. Chen YT, Deng Q, Che X, Zhang JW, Chen YH, Zhao DB, Tian YT, Zhang YW, Wang CF. Impact of body mass index on complications following pancreatectomy: ten-year experience at National Cancer Center in China. World J Gastroenterol. 2015;21(23):7218–24.
42. Sfarti C, Trifan A, Hutanasu C, Cojocariu C, Singeap AM, Stanciu C. Prevalence of gastroparesis in type 1 diabetes mellitus and its relationship to dyspeptic symptoms. J Gastrointestin Liver Dis. 2010;19(3):279–84.
43. Liu Q, Zhao Z, Zhang X, Wang W, Han B, Chen X, Tan X, Xu S, Zhao G, Gao Y, et al. Perioperative and Oncological outcomes of Robotic Versus Open Pancreaticoduodenectomy in Low-Risk Surgical candidates: a Multicenter Propensity score-matched study. Ann Surg. 2023;277(4):e864–71.
44. Snyder RA, Ewing JA, Parikh AA. Delayed gastric emptying after pancreaticoduodenectomy: a study of the national surgical quality improvement program. Pancreatology: Official J Int Association Pancreatology (IAP) [et al]. 2020;20(2):205–10.
45. Zhenli L, Yibing Z, Yuanzhi N, Liang L, Lindi X, Yang G, Shuaishuai Z, Yufu T. Updating the paradigm of prophylactic abdominal drainage following Pancreatoduodenectomy (review article). Int J Surg. 2024.
46. Yu d, Lin L, Yahui L, Shupeng W. Prevalence of Malnutrition and the Value of Predicting Pancreatic Fistula in patients with laparoscopic pancreatoduodenectomy. J Laparoendosc Adv Surg Tech A. 2023;33(10).
47. Bruno O, Brancatelli G, Sauvanet A, Vullierme MP, Barrau V, Vilgrain V. Utility of CT in the diagnosis of pancreatic fistula after pancreaticoduodenectomy in patients with soft pancreas. AJR Am J Roentgenol. 2009;193(3):W175–80.
48. Xu-Feng Z, Guo-Zhi Y, Qing-Guang L, Xue-Min L, Bo W, Liang Y, Si-Nan L, Hong-Ying C, Yi L. Does Braun enteroenterostomy reduce delayed gastric emptying after pancreaticoduodenectomy? Med (Baltim). 2014;93(7).
49. Fujii T, Nakao A, Murotani K, Okamura Y, Ishigure K, Hatsuno T, Sakai M, Yamada S, Kanda M, Sugimoto H, et al. Influence of Food Intake on the Healing process of postoperative pancreatic Fistula after Pancreatoduodenectomy: a multi-institutional Randomized Controlled Trial. Ann Surg Oncol. 2015;22(12):3905–12.
50. Mizrahi J, Surana R, Valle J, Shroff R. Pancreatic cancer. Lancet (London England). 2020;395(10242):2008–20.
51. Xu S, Zhang X-P, Zhao G-D, Zou W-B, Zhao Z-M, Hu M-G, Gao Y-X, Tan X-L, Liu Q, Liu R. Robotic versus open pancreaticoduodenectomy for distal cholangiocarcinoma: a multicenter propensity score-matched study. Surg Endosc 2022.
52. Wenchuan W, Jin H, John LC, Martin M, Kevin S, Nita A, Neda R, Joseph H, Lei Z, Daniel L et al. The impact of postoperative complications on the administration of adjuvant therapy following pancreaticoduodenectomy for adenocarcinoma. Ann Surg Oncol. 2014;21(9).
53. Murakami Y, Uemura K, Sudo T, Hashimoto Y, Kondo N, Nakagawa N, Sasaki H, Sueda T. Early initiation of adjuvant chemotherapy improves survival of patients with pancreatic carcinoma after surgical resection. Cancer Chemother Pharmacol. 2013;71(2):419–29.

Publisher's note