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Clinical Value of Robot-Assisted Pancreaticoduodenectomy in the Treatment of Locally Advanced Pancreatic Head Cancer

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1. Abstract

1.1. Objective: To comprehensively evaluate the feasibility and safety of robot-assisted pancreaticoduodenectomy in the management of patients with pancreatic head cancer staged IA to III.

1.2. Methods: We conducted a retrospective analysis of perioperative clinical data from a cohort of 101 patients who underwent robot-assisted pancreaticoduodenectomy performed by our surgical team between July 2015 and September 2024.

1.3. Results: Of the 101 cases, 51 were diagnosed with pancreatic head ductal adenocarcinoma, stratified as follows: 6 cases in stage IA, 11 in stage IB, 3 in stage IIA, 19 in stage IIB, and 12 in stage III. The remaining 50 cases involved other tumor types. Preoperatively, 13 patients underwent percutaneous transhepatic cholangial drainage, with biliary stent placement in 2 cases. Under robotic assistance, 4 cases required vascular reconstruction, including 1 arterial reconstruction, 2 venous reconstructions, and 1 combined arterial and venous reconstruction. The mean intraoperative duration was (168.9 ± 78.6) minutes, with an intraoperative blood loss averaging 180.4 (150-1000) milliliters. Postoperatively, 15 complications were observed. Specifically, 2 cases of gastric emptying disorder resolved after gastrointestinal decompression and pancreatic enzyme inhibition, leading to successful discharge. Additionally, 13 cases of pancreatic fistula were noted, with 3 of them being grade C and resulting in intra-abdominal hemorrhage. Two were managed with open abdominal exploration and hemostasis; one patient with grade C fistula died of multiorgan failure due to novel coronavirus infection.

1.4. Conclusion: robot-assisted pancreaticoduodenectomy, using artery-centric dissection, skilled anastomosis techniques, coupled with attention to Cholecystoenteric and pancreatic-enteric anastomosis quality as well as drain placement, shows safety and feasibility in treating locally advanced pancreatic head cancer. With postoperative chemotherapy, it may achieve a high 5-year survival rate.

2. Introduction

Pancreaticoduodenectomy(PD),ahighlycomplexabdominalsurgery encompassing multiple anastomoses - pancreaticojejunostomy, hepaticojejunostomy, and gastrojejunostomy—is the gold standard for treating invasive pancreatic head tumors [1]. Initially, Robot-assisted Pancreaticoduodenectomy (RPD) was limited to stage IA pancreatic head cancer; however, for stage IB and advanced cases, open PD (OPD) was favored [2]. Our team, leveraging OPD's artery-centric surgical strategy and vascular anastomosis techniques, optimized RPD by emphasizing hepaticojejunostomy and pancreaticojejunostomy quality and rational drainage placement. We then assessed clinical efficacy of RPD in locally advanced pancreatic head cancer. The results are as follows.

3. Materials and methods

3.1. Data analysis

Descriptive statistics summarized perioperative characteristics and postoperative outcomes. Categorical variables were presented as percentages or frequencies, and continuous variables as (mean ± standard deviation) or mean (median-interquartile range). The chi-square test compared categorical variables between groups. The Shapiro-Wilk test assessed normal distribution, followed by the independent t-test for normally distributed variables and the Mann-Whitney U test for abnormally distributed ones. Statistical significance was set at $P < 0.05$, and analyses were conducted using SPSS 27.0.

3.2. Clinical data

A retrospective analysis was conducted on data from patients admitted to Shanghai Changhai Hospital from July 2015 to September 2024. Inclusion criteria comprised: (1) complete clinical records; (2) RPD without intraoperative transfer; (3) malignancy without distant metastasis; (4) surgery by a single team; (5) no liver or renal insufficiency; (6) no severe malnutrition. A total of 101 patients met these criteria. RPD was approved by our hospital's ethics committe, with informed consent obtained from patients and family members.

101 patients age (62.4 ± 9.2) years, 61 male, 40 female, 14 diabetes, 36 hypertension, 2 hyperlipidemia, 4 heart disease, 3 hepatitis, 13 percutaneous transhepatic cholangial drainage treatment before surgery, and 2 bile duct stents. Imaging examination showed 4 cases of vascular invasion, with 61 tumors located in the pancreatic head, 22 in the duodenal ampulla, 12 in the distal common bile duct, and 6 in the duodenum. The preoperative clinical data of the patients are shown in Table 1.

Table 1: Preoperative clinical data.

Variables	Numeric value
Age(years)	62.40± 9.20
Male(case)	61
Female(case)	40
Diabetes (case)	14
Hypertension(case)	36
Hyperlipidemia(case)	2
Heart disease(case)	4
Hepatitis (case)	3
Preoperative PTCD(case)	13
Implantation of a bile duct stent(case)	2
Heart rate (bpm)	76.00± 5.80
Clinical laboratory data	
CEA(ng/ml)	3.20(2.30-2.11)
CA199(U/ml)	104.80(26.40-122.00)
CA125(U/ml)	18.20(13.70-14.30)
AFP(U/ml)	3.70(3.50-1.80)
Hemoglobin (g/l)	123.80 ± 15.70
C-reactive protein (mg/l)	9.10（3.90-7.00)
PCT(ng/ml)	0.04 ± 1.50
White blood cells (x 109/l)	6.20(5.80-2.50)
albumin (g/l)	40.20(40.00-6.50)
Prealbumin (mg/l)	206.90(203.00-76.00)
Gluconate transaminase (U/l)	110.80(70.00-132.00)
Aspartate aminotransferase (U/l)	73.00(39.00-76.00)
Total bilirubin (µmol/l)	73.20(22.50-113.30)
Blood creatinine (µmol/l)	66.50(64.00-18.00)
Fibrinogen (g/l)	5.00(4.80-2.20)

4. Surgical Procedure

The average duration of surgery for 101 patients treated with RPD was (168.9 ± 78.6) min, with an average intraoperative blood loss of approximately 180.4 (150-100) ml. Intraoperatively, tumor invasion of blood vessels was observed in 4 cases, with no distant metastasis; our team completed 1 case of right hepatic artery reconstruction, 2 cases of portal vein reconstruction, and 1 case of combined hepatic artery and portal vein reconstruction under robotic assistance (Table 2).

The RPD surgery was conducted with the patient in the head-up, feet-down position, utilizing a five-trocar configuration. Key instruments included bipolar forceps, atraumatic graspers, electrocautery scissors, needle drivers, and dissecting clamps. The surgery was systematically divided into resection and reconstruction phases.

Table 2: Intraoperative and postoperative clinical data Pancreatic fistula included intra-abdominal bleeding and 30-day mortality POD (postoperative days).

Intraoperative clinical data		
	Variables	Numeric value
	Surgical duration (min)	168.90±78.60
	Blood loss during surgery (ml)	180.40(150-100)
	Intraoperative transfusion (case)	0
	Pancreatic duct diameter (cm)	0.30±0.10
	Total bile duct diameter (cm)	1.30±0.30
	Vascular invasion (case)	4
	Arterial reconstruction (case)	1
	Vein reconstruction(case)	2
	Arterial and venous reconstruction(case)	1
	Transit(case)	0
	Distant metastasis(case)	0
	Postoperative clinical data	
	Variables	Numeric value
	Pancreatic fistula (case)	13
	Biliary fistula (case)	0
	Gastric fistula (case)	0
	Gastric emptying disorder(case)	2
	Abdominal bleeding (case)	3
	Abdominal infection (case)	0
	30-day mortality (case)	1
Test indicators on the first day after surgery	Number of days in hospital (days)	21.50(18-11)
	Pancreatic fistula (case)	13
	Hemoglobin (g/l)	110.10±15.50
	C-reactive protein (mg/l)	63.10(53.90-63.70)
	PCT(ng/ml)	1.20(0.20-0.40)
	White blood cells (× 109/l)	12.30±4
	albumin (g/l)	33.30(33-6)
	Prealbumin (mg/l)	147.60(146-60)
	Gluconate transaminase (U/l)	182.50(124-153)
	Aspartate aminotransferase (U/l)	133.40(77-125)
	Total bilirubin (μmol/l)	56.50(28.20-61)
	Blood creatinine (μmol/l)	65.10(63-23)
	Fibrinogen (g/l)	5 (4.80-2.20)
	Heart rate on day 1 (bpm)	81(80-19)
	Abdominal drainage POD1(ml)	340(260-440)
	Abdominal drainage POD2(ml)	328.50(250-408)
Postoperative physiological monitoring indicators	Abdominal drainage POD3(ml)	288(202-352)
	Basal gastric volume POD1(ml)	139.40(70-195)
	Basic gastric volume POD2(ml)	196(100-290)
	Basal gastric volume POD3(ml)	250(200-300)

4.1. Resection

1. Separate the gastrocolic ligament and divide the stomach.

2. Dissect the hepatic artery - superior margin of the pancreas - gastroduodenal artery (HPG) triangle, transect the Gastroduodenal Artery (GDA), expose the Portal Vein (PV) and suspend it (Figure 1).

3. Ligate the cystic artery along the hepatic artery and dissect the gallbladder.

4. Exposure of the inferior aspect of the pancreas, revealing the Superior Mesenteric Vein (SMV) and Superior Mesenteric Artery (SMA), with each being suspended, and transverse sectioning of the pancreatic neck.

5. Kocher incision, dissecting the descending part and horizontal part of the duodenum, as well as the dorsal side of the pancreatic head.

6. The descending and horizontal portions of the duodenum were suspended with triple sutures, the Treitz ligament was transected, the D-hole (the natural passage opening between the duodenum and jejunum) was opened, and the proximal jejunum was exteriorized and transected.

7. Dissect the pancreatic uncinate process along the SMA, resect the specimen.

4.2. Gastrointestinal reconstruction

1. The pancreaticojejunostomy is performed using the "HO" or "Pocket" anastomosis technique, starting from the proximal jejunum of D-hole.

2. Hepaticojejunostomy is decided by the size of the bile duct whether to place a temporary stent tube.

3. Anterior colonic or L-shaped jejunal pull-up for gastrojejunal anastomosis.

4. Place two drains in the abdominal cavity

4.3. Vascular reconstruction

1. PV reconstruction: clamping of the portal vein, proximal and distal ends of the superior mesenteric vein, then cutting the invaded vein ends, continuous suture of the portal vein with the SMV using 5-0 prolene thread.

2. Hepatic artery: after blocking the proximal and distal ends of the artery with arterial clamps, the invaded vessel is resected and an end-to-end anastomosis is performe.

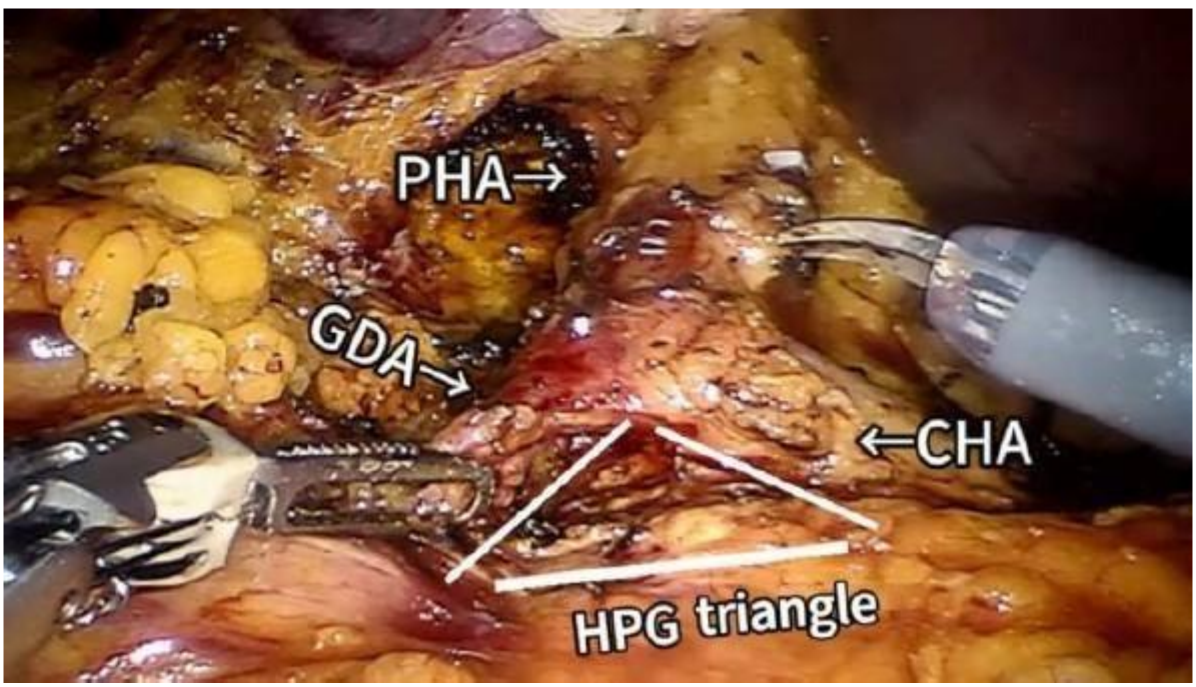

Figure 1: Anatomy of PHA, GDA, CHA, and HPG triangles.

5. Results

Postoperative monitoring encompassed heart rate, nutritional indices, inflammatory markers, infection indicators, hepatic and renal function; along with abdominal drainage volume and basal gastric acid output (Table 2). The mean hospital stay post-surgery was 21.5 (11-18) days. Complications arose in 15 patients, including 2 cases of delayed gastric emptying resolved by gastrointestinal decompression and pancreatic enzyme inhibition. Thirteen patients developed pancreatic fistulas: 10 were grade B and managed with abdominal drainage, continuous drainage, and enzyme inhibition; 3 were grade C with abdominal bleeding, of which 2 recovered post-exploratory laparotomy and hemostasis, while 1 fatality occurred due to multiple organ failure secondary to novel coronavirus infection.

Classified by tumor location, 61 cases involved the pancreatic head (highest proportion), followed by 22 in the duodenal bulb, 12 in the distal bile duct, and 6 in the duodenum. Among the 101 RPD cases, 51 were PDAC and 50 were other pathological types, including rare entities such as acinar cell carcinoma, neuroendocrine tumors, intraductal papillary mucinous neoplasms, adenosquamous carcinoma, sarcoma, duodenal adenocarcinoma, gastrointestinal stromal tumors, and intraepithelial neoplasia (Table 3). Comparison of surgical outcomes between PDAC and other tumor types revealed statistically significant differences in postoperative white blood cell count elevation (P=0.01), procalcitonin levels (P=0.03), and average peritoneal drainage over three days (P=0.04). No significant distinctions were observed in perioperative difference of heart rate, total bilirubin, aspartate or alanine aminotransferases, albumin, hemoglobin, gastric juice output, average peritoneal drainage, operative duration, intraoperative blood loss, hospital stay, or complication rates within three days postoperatively.

A data analysis of 51 PDAC cases by pathological stage revealed distributions as follows: 6 (12%) in stage IA, 11 (22%) in stage IB, 3 (6%) in stage IIA, 19 (37%) in stage IIB, and 12 (24%) in stage III (Figure 2). The mean tumor diameter was (2.73 ± 1.40) cm. Statistical analysis showed no significant differences across stages in tumor markers, pancreatic fistula indicators, blood loss, liver function indices, infection markers, nutritional indices, postoperative complication rates, drainage volume, hospital stay, operative duration, or intraoperative blood loss (Table 4).

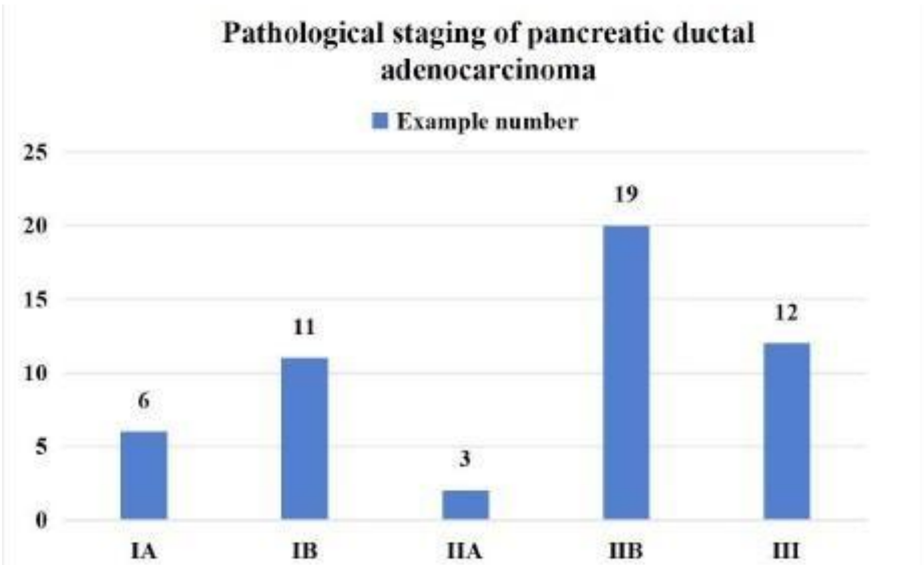

Figure 2: Pathological staging of PDAC.

Table 3: Comparison of perioperative clinical data according to pathological type, n(%).

Variable	Pancreatic ductal adenocarcinoma (n = 51)	Other pathological types (n = 50)	P-value
Pancreatic fistula indicators			
Heart rate-DIF↑ (times/min)	2.10± 10.20	7.10±16.70	0.1
Blood loss indicators			
Hb-DIF↓(g/l)	15.60± 13.40	11.40±12.70	0.13
	liver function index		
Total bilirubin-DIF↓(μmol/l)	27.7(2.6-64.2)	5.60（0.80-22.40)	0.1
Aspartate aminotransferase-DIF↑ (μmol/l)	59.8(41.0-82.8)	61(22-77.50)	0.87
Alanine aminotransferase-DIF↑ (μmol/l)	55.0(41.5-97.5)	89.50(33-87)	1
Infection indicators			
White blood cell-DIF ↑(x109/l）	5± 3.40	7.30± 4.10	0.01c
Postoperative PCT (ng/ml)	1.40(0.20-0.30)	1.10(0.40-1.10)	0.03c
Nutritional indicators			
Albumin-DIF↓ (g/l)	7.70（8-6.70)	6(7-7.5)	0.2
Intraoperative data			
Intraoperative blood loss (ml)	170.10±72.50	166.80±77.60	0.83
Surgical duration (min)	198.10(150-100)	175.90(120-10)	0.11
Postoperative data			
complication(case)	7(13.70)	8(16)	0.74
Gastric juice drainage on MPOD1-3 (ml)	209.20(167-320)	168(150-293.50)	0.63
Intra-abdominal drainage on MPOD1-3 (ml)	276(207-349.50)	359(300-386.50)	0.21
days in hospital (days)	20(19-11)	23(17-10)	0.52

C: statistically significant. Gastric juice drainage on MPOD1-3: Gastric juice drainage on Mean values from 1–3 days after surgery. Intra-abdominal drainage on MPOD1-3：Intra-abdominal drainage on Mean values from 1–3 days after surgery

Table 4: Comparison of perioperative clinical data of PDAC according to pathological staging, n(%).

Variable	IA(n=6)	IB(n=11)	IIA(n=3)	IIB(n=19)	III(n=12)	P-value
Tumor indicators						
CEA(ng/ml)	1.90±0.81	3±2.30	1.80±0.20	3(93-3)	2.80±1.70	0.28
CA199(U/ml)	134.80±115.20	256.30±312	250.40±210.70	219.60(88.70-189.60)	188.90(144.30-322.40)	0.98
CA125(U/ml)	15.30±7.20	18.±11.50	17.30±6.20	19.90(17.60-17.90)	21.30±11.80	0.64
AFP(ng/ml)	2.20±0.80	3(2.50-2.50)	3.10±1	4.40±1	4.20±1.70	0.05
Pancreatic fistula indicators						
Heart rate-DIF ↑ (times/min)	5.30±13.60	4.7 （1.50-12.30)	11±15.60	0.30±9.50	6.10±58.40	0.31
Blood loss indicators						
Hb-DIF↓(g/l) liver function index	16.70±7.60	20.50±18	23±12.70	13.50±25.60	12.10(7-14)	0.71
liver function index						
Total bilirubin-DIF↓ (μmol/l)	28.40±38.10	15.20±28.80	28.30±45.60	30.20(1.60-100)	36.30(2.6-84.0)	0.31
Aspartate aminotransferase-DI F↑(μmol/l)	86.0±56.4	179.0(20.0-353.5)	93.50±64.30	8.30±101	134.90±136	0.11
Alanine aminotransferase-DI F↑(μmol/l)	114.70±87.80	123 (20-270.50)	87±66.90	1.40 （43-88.30)	124.70±135.30	1
Infection indicators						
White blood cell-DIF ↑(×109/l)	6.70±1.50	5.40±4.80	0.80±3.40	5.90±2.50	5.60±3.20	0.29
Postoperative PCT (ng/ml)	0.90±1.40	0.20±0.10	0.20±0.20	0.30(0.10-0.30)	5.50(0.20-0.40)	0.34
Nutritional indicators						
Albumin-DIF↓(g/l)	8.30±6.10	10(8-8.60)	8.50±0.70	8.60±4.80	7.70±4.70	0.86
Intraoperative data						
blood loss (ml)	156.0±50.6	182.0(150.0-100.0)	175.0±45.6	175.0(150.0-100.0)	172.0(150.0-100.0)	0.88
Surgical duration (min)	188.30±113.40	160±70.40	185±120.20	205.60±96.40	198.90±63.50	0.98
Postoperative data						
complication (case)	1(16.70)	2(18.20)	0(0)	2 (10.50)	2(16.70)	0.07
Gastric juice drainage (ml) on MPOD1-3	28.30±19.60	136.30±143.90	19.50±364	286.80±204	146.20±104	0.04c
Intra-abdominal drainage (ml) on MPOD1-3	385±114.30	463.70±441.90	623±721	263.60±206	417.70±226.50	0.72
Days in hospital (days)	19.30±5.70	13.80±4.50	22±7	19±8.20	23(15-16.50)	0.71

DIF: preoperative and postoperative day 1 difference. ↑: increase value. ↓: decrease value. C: Statistically significant. Gastric juice drainage on MPOD1-3: Gastric juice drainage on Mean values from 1–3 days after surgery. Intra-abdominal drainage on MPOD1-3：Intra-abdominal drainage on Mean values from 1–3 days after surgery

6. Prognosis

Our team conducted a follow-up study on patients ranging from 3 months to 5 years post-treatment. The postoperative assessments demonstrated a pain score of 1.6(1.0-1.0), self-care 3.8 (3.0-2.0), daily activities 3.5 (3.0-3.0), anxiety 2.1 (2.0-2.0). Adjuvant treatment chemotherapy efficacy was administered by monitoring the efficacy of CA199. Notably, when postoperative CA199 levels did not normalize, primarily using the AG regimen (paclitaxel + gemcitabine). 85(85.0%) patients can remain at the normal level within 6 months without evidence of tumor recurrence. In some patients, CA199 levels decreased following AG chemotherapy and then switched to maintenance therapy with TGO. Excluding one death due to novel coronavirus infection leading to multi-organ failure, the overall 1-year, 3-year, and 5-year survival rates among the 100 follow-up cases were 92%, 33.0%, and 17.0%, respectively.

7. Discussion

The Controversy surrounding RPD for locally advanced pancreatic head cancer focuses on its thoroughness, safety, and patient benefit, particularly for stage III patients often recommended neoadjuvant chemotherapy. However, clinical observations indicate that advanced pancreatic cancer without distant metastasis, coupled with a comprehensive CA199 assessment, is amenable to RPD and associated with a favorable prognosis. In patients with locally advanced pancreatic head cancer at stage III, where vascular surgical techniques can be employed for safe resection and reconstruction of involved vessels, RPD offers therapeutic benefits to those who have lost treatment opportunities due to insensitivity to neoadjuvant therapies. Our team treated 51 patients with locally advanced pancreatic head cancer using RPD surgery. Postoperative quality of life was significantly improved compared to OPD. Notably, 85(84.2%) patients showed no signs of recurrence within six months post-surgery, with a 1-year survival rate of 92.0%, a 3-year survival rate of 33.0%, and a 5-year survival rate of 17.0%. To ensure the radical efficacy and safety of RPD, the following points deserve emphasis:

7.1. Precise preoperative evaluation and the selection of surgical cases

The 2023 guidelines on robotic-assisted pancreatic surgery indicate that patients with marginally resectable and locally advanced pancreatic cancer may derive greater benefit from RPD [3]. Our team advocates for RPD in locally advanced cases where PET-CT excludes distant metastases, CA199 levels are <500 U/ml, and patients are preoperatively well-nourished (prealbumin >100 mg/l). It has also been reported in the literature that: (1) for tumors with a diameter < 2cm, CA199 < 1000 (U/ml); (2) for tumors < 3cm in diameter, CA199 < 500 (U/ml); (3) for tumors < 4cm in diameter, CA199 < 150 (U/ml); (4) patients with tumors < 5cm in diameter and CA199 < 50 (U/ml) have significantly prolonged disease-free survival and overall survival [4]. Preoperatively, imaging assesses the relationship between blood vessels and tumors. The length of vessels for pre-resection and post-resection tension are pivotal for RPD in cases of vascular invasion. Our comparative analysis of 101 patients showed that RPD patients experienced minimal fluctuation in postoperative nutritional indices (albumin, prealbumin) compared to preoperative levels, indicating lesser surgical trauma and faster recovery. Reduced intraoperative blood loss resulted in minimal postoperative hemoglobin fluctuations and lower incidence of severe anemia. The impact on liver and kidney function was negligible, leading to an effective improvement in quality of life. Furthermore, perioperative data demonstrated no significant statistical difference based on pathological type and stage, indicating the suitability of RPD for pancreatic head cancer resection. For pancreatic tumors with rare pathological types that are insensitive to neoadjuvant therapy, such as pancreatic head sarcoma, surgery is also recommended even if there is vascular invasion.

7.2. The surgical strategy focuses on the artery and is protected by vascular techniques

In the 1950s, the Michels autopsy study reported that among 200 cases, approximately 26% exhibited variation in the Right Hepatic Artery (RHA) and 27% in the Left Hepatic Artery (LHA) [5-7]. However, preoperative mastery of vascular variations is often hindered by the limitations of CT imaging due to its thickness [8]. Clear intraoperative identification of the arterial structure is crucial for surgical success. Utilizing the inherent anatomical landmarks of the liver, the GDA, and the upper edge of the pancreas to form the "HPG triangle" can effectively prevent damage to the hepatic artery and posterior portal vein. Additionally, the “HPG triangle” aids in distinguishing the course and length of the GDA, delineating the layers of the hepatic duodenal ligament, which is beneficial for lymph node dissection and assessing abnormal hepatic artery pathways. Our team typically dissects the “HPG triangle” at the pancreatic upper edge and skeletonizes the artery to expose the SMV at the pancreatic neck. In cases of severe pancreatic inflammation or post-neoadjuvant chemotherapy where the HPG triangle is challenging, we expose the portal vein along the splenic vein and identify the pancreas' left suture line to locate the triangle. Furthermore, we meticulously dissect the GDA until it enters the pancreas to prevent injury to any ectopic right hepatic artery originating from the GDA.

For patients with tumor vascular invasion, it is recommended to free SMA throughout the whole procedure [9]. We dissect the SMV and SMA at the pancreatic lower edge or transverse colon root, suspend them, and expose the “HPG triangle” at the pancreatic upper edge while suspending the PV and CHA. We then treat the uncinate ligament from bottom to top along the SMA, ultimately addressing affected vessels. This approach enables rapid arteriovenous control, minimizes bleeding interference, and enhances surgical safety. In an advanced pancreatic cancer RPD case, we encountered an uncommon hepatic artery originating from the SMA root, coursing through the pancreatic head, with a GDA arising within pancreatic parenchyma. An artery-centered surgical strategy proved advantageous in managing this anatomical variant (Figure 3). Complete SMA skeletonization and arteriovenous separation or suspension not only prevented iatrogenic vascular damage but also augmented surgical safety and facilitated R0 resection radicality [6]. In the case of bleeding during vessel separation and blurred vision, the suction device is used to attract and flush the view and locate the bleeding point. The bipolar forceps (2- robotic arm) or needle holder (1- robotic arm) was utilized to swiftly clamp the vascular tear. An assistant secured the distal end of vessel with a hemolok clamp via an auxiliary hole, while the 1-arm needle holder was employed for suturing to achieve rapid hemostasis.

7.3. Value the quality of anastomosis

Pancreaticojejunostomy (PJ) and Choledochojejunostomy (CJ) fistulas are prevalent and perilous complications after RPD. Emphasizing the quality of CJ is crucial for minimizing postoperative complications. To address both normal soft pancreas and inflamed, fragile pancreas, we innovated the “HO”halfpurse binding for PJ, which concentrates tension on the suture line, sparing pancreatic tissue and ensuring close pancreatic-jejunal anastomosis without cavities, effectively isolating the PV to prevent fistulas, erosion, and bleeding [10]. Leveraging advancements in suture materials, we introduced "Pocket" PJ using barbed thread, simplifying the procedure. The posterior pancreatic wall was continuously sutured with barbed thread, achieving double-layer pancreatic duct-jejunum and full-thickness anastomosis, while the anterior wall was sutured using horizontal mattress stitches. This method is efficient, time-saving, and suitable for both soft and fragile pancreatic tissue. In 101 RPD cases, 51 underwent "HO" anastomosis with 5 grade B and 2 grade C fistulas; 50 underwent "Pocket" anastomosis with 5 grade B and 1 grade C fistula (no statistical difference). Overall, postoperative pancreatic fistula incidence was 12.9%. For CJ, PDS II absorbable suture was used. When the common hepatic duct was not dilated, we temporarily inserted a size 10 ventricular drainage tube post-posterior wall anastomosis to prevent obstruction and subsequent bile leakage.

7.4. Emphasis on the placement and maintenance of drainage tubes

For large-scale surgical procedures, routine drain placement effectively prevents intra-abdominal exudate accumulation and subsequent infection. Pancreatic fistula following pancreatoduodenectomy is a notable cause of postoperative hemorrhage. Based on our expertise, we strategically place the drainage tube behind the choledochojejunal anastomosis, with the front end located above the upper edge of the pancreaticojejunal anastomosis using robot's arm number 3. Place the drainage tube at the robot's arm number 1 behind the gastrojejunal anastomosis, in front of the pancreaticojejunal anastomosis, reaching the front of the choledochojejunal anastomosis. In cases of pancreatic fistula, continuous irrigation can be implemented to dilute digestive enzymes, thereby mitigating the incidence of fistulas and associated mortality risks [11].

Although RPD exhibits longer operative times compared to OPD [12], it significantly minimizes blood loss owing to the robotic EndoWrist's flexibility, enhanced visual field, and energy platform assistance [13]. A multicenter study revealed comparable complication rates between RPD and OPD but noted a reduced incidence of postoperative grade C pancreatic fistulas with RPD [11,14]. Pancreatic disease often entails metabolic disturbances and nutritional depletion, with postoperative nutritional status influencing prognosis; notably, albumin <30g/L elevate complication risks [15]. RPD induces less trauma and minimal albumin fluctuation from preoperative levels, decreasing postoperative wound infections. Furthermore, RPD facilitates gastrointestinal function recovery with less gastric retention and peristalsis interference. Compare to OPD, progressive pancreatic cancer patients tolerate RPD better, offering more surgical opportunities and earlier postoperative chemotherapy, thereby prolonging survival. Postoperative life assessments indicate lesser pain and anxiety in RPD patients compared to OPD, enabling independent activity and reduced self-care time, ultimately enhancing the quality of life after pancreatic cancer surgery.

The treatment guidelines for pancreatic cancer hinge on defining tumoral arterial invasion. Tumors enveloping the SMA >180° in the pancreatic head or uncinate process are deemed unresectable, tumor invasion <180° is relatively resectable, but the invasion of large vessels especially PV and SMV is a relative contraindication for minimally invasive methods [5]. Advancements in minimally invasive technology have led some centers to report advantages of external robotic systems in vascular reconstruction [16]. In our RPD practice, we acknowledge the specific benefits of robot in vascular anastomosis, notably its enhanced field of view, filtered hand anastomosis, and reduced operative time. Among 12 pancreatic cancer cases with vascular involvement, 4 underwent revascularization with no postoperative complications and were discharged 11-28 days postoperatively.

Upon review, we conclude that RPD is a promising and viable treatment for advanced pancreatic cancer. Nonetheless, due to the small sample size, further multicenter clinical studies are essential to bolster the evidence-based support for this approach.

8. Declarations

8.1. Ethics approval and consent to participate

Ethics approval is not applicable. This paper is original and has not been submitted elsewhere for publication. All authors have read and approved the content and agree to submit it for consideration for publication.

8.2. Authors' contributions

Keke Lv wrote the manuscript and drew the figures. Hao Hu as a co-first author who participated in completing the surgery, provide surgical images, and perform translation and article revision, contributing equally with the first author. Tianlin He is the chief surgeon and provide patient data. Tianlin He, Zixin Liu, Zhongfei Zhu, Gang Nie, Kailian Zheng, Yayu Huang, Chenxi Zheng all participated in the operation and provided the conceptual suggestions from his professional perspective and revised the manuscript. All authors read and approved the final manuscript.

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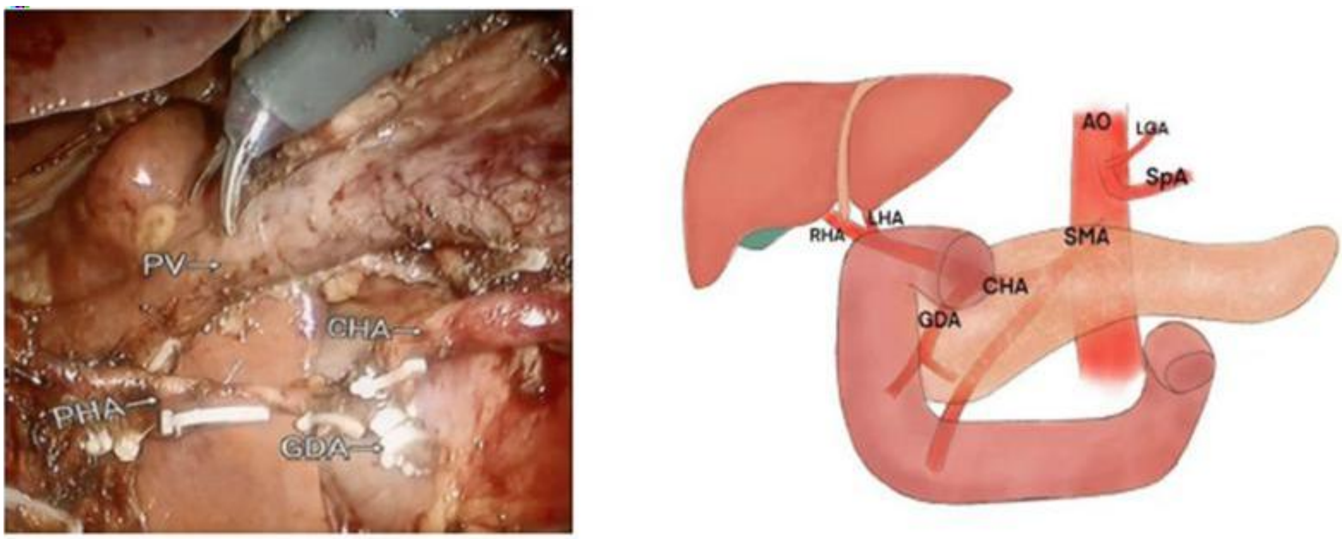

Figure 3: Physical image and hand-drawn illustration of variant arterial anatomy.

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