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Efficacy of Chen's pancreaticojejunostomy for patients with soft pancreatic texture and small main pancreatic duct in laparoscopic pancreaticoduodenectomy

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Abstract

Background Pancreaticojejunostomy (PJ) is the key step in laparoscopic pancreaticoduodenectomy (LPD), the quality of which directly affects the incidence of postoperative pancreatic fistula (POPF). Soft pancreatic texture and a small main pancreatic duct (MPD) are risk factors for POPF, which also increase surgeons' difficulty with PJ. Chen's pancreaticojejunostomy is simple, feasible, and reproducible. This study aims to evaluate the clinical effects of Chen's pancreaticojejunostomy for patients with soft pancreas texture and a small MPD in LPD.

Methods The clinical data of 112 patients who underwent LPD with Chen's pancreaticojejunostomy in Xiangyang Central Hospital from February 2018 to December 2023 were analyzed retrospectively. Summarize and evaluate the critical clinical indicators and postoperative complications during the perioperative period.

Results All 112 patients successfully underwent LPD. The median operation time was 300 min, the median PJ time was 27 min, and the median intraoperative blood loss was 100 ml. 8 patients (7.1%) had POPF, all of which had grade B POPF, and no grade C POPF occurred. Postoperative mortality was 1.8% (2/112) within 90 days, and no patient died due to POPF. Among 45 cases (40.2%) with soft pancreatic texture, five patients (11.1%) developed POPF. Among 41 patients (36.6%) with a diameter of MPD ≤ 3 mm, four patients (9.8%) developed POPF. The texture of the pancreas and the diameter of MPD did not affect postoperative complications ($P > 0.05$).

Conclusions Chen's pancreaticojejunostomy is simple, safe and reliable, which is suitable for the condition of soft pancreatic texture or the small MPD.

Keywords Pancreaticojejunostomy, Laparoscopic pancreaticoduodenectomy, Postoperative pancreatic fistula, Postoperative complications

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Introduction

Pancreaticoduodenectomy (PD) is generally considered to be the only radical treatment for distal bile duct cancer, duodenal papillary cancer, periampullary cancer, and pancreatic head cancer, which is one of the most complex abdominal operations. With the advancement of minimally invasive technology and the accumulation of surgical experience, the safety and effectiveness of laparoscopic pancreaticoduodenectomy (LPD) have been widely confirmed. Now, LPD is typically performed in many medical centers around the world. However, there are still many postoperative complications, among which pancreatic fistula is the most common, complex, and very dangerous complication [1, 2]. Postoperative pancreatic fistula (POPF) can lead to intra-abdominal infection, sepsis, and abdominal hemorrhage. If not treated in time, POPF can lead to organ failure and even death. Therefore, how to reduce the incidence of POPF in the perioperative period has always been a hot topic for surgeons. Pancreaticojejunostomy (PJ) is the most critical step in LPD. Its quality directly determines the incidence of POPF, which is of great significance [3, 4]. To reduce the occurrence of POPF, various PJ methods have been proposed, such as the duct-to-mucosa technique, the invaginated anastomosis technique, and their modifications [5]. However, there is still no ideal anastomosis method to avoid the occurrence of pancreatic fistula [6–8]。.

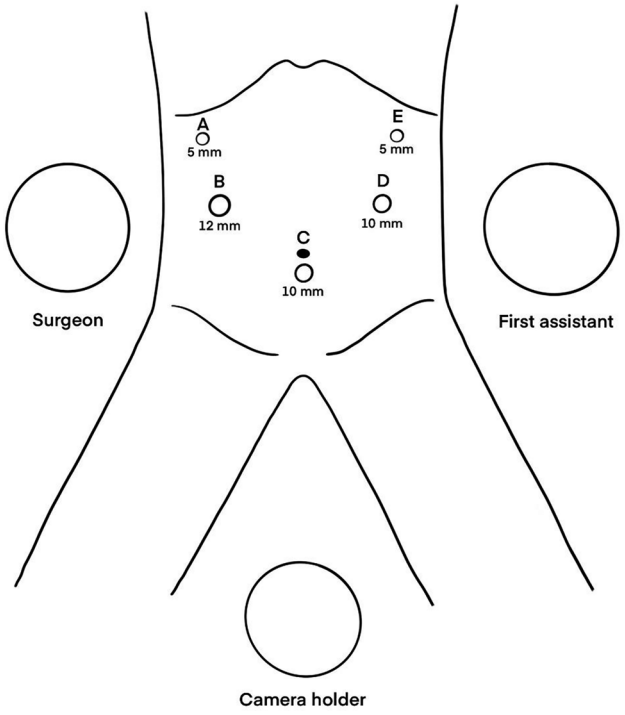

Fig. 1 Diagram of trocar placement for LPD. A-B: a 5 mm trocar (A) and a 12 mm trocar (B) are used by the surgeon; C: a 10 mm trocar is placed first for optical observation; D-E: a 10 mm trocar (D) and a 5 mm trocar (E) are used by the assistant surgeon

Generally, the soft texture of the pancreas and the small main pancreatic duct (MPD) size (≤ 3 mm) are known risk factors for POPF [9] which increases the difficulty of surgical operations, and surgeons have been trying to find a way out of this dilemma. Chen's pancreaticojejunostomy was proposed in 1995, which is the jejunal inversion PJ with a longitudinal U-shaped suture through the pancreas [10–12] and has been applied to LPD in our center since February 2018. There are few research reports on the clinical application of this technique in the difficult conditions of soft pancreas and small main pancreatic duct size under laparoscopy. The aim of this study is to evaluate the clinical efficacy of Chen's pancreaticojejunostomy for these difficult conditions in LPD.

Materials and methods

Patient selection

This study included clinical data of patients who underwent LPD in Xiangyang Central Hospital affiliated with Hubei University of Arts and Sciences from February 2018 to December 2023. Inclusion criteria: (1) patients who underwent LPD with Chen's pancreaticojejunostomy; (2) patients without major organ dysfunction and obvious distant metastasis; (3) patients with complete clinical data. The following were exclusion criteria: (1) patients who underwent laparotomy or were converted to laparotomy during LPD; (2) patients who underwent other PJ techniques; (3) patients who had major organ dysfunction and could not tolerate surgery or had tumors in other parts of the body; (4) patients with missing clinical data.

Preoperative preparation

All patients met the surgical requirements. Adequate preparation was given before surgery, including respiratory function exercises, correction of water-electrolyte and acid-base imbalance, and control of blood sugar and blood pressure. In addition, for patients with apparent obstructive jaundice (serum total bilirubin level ≥ 250 μmol/l), our center gave priority to percutaneous transhepatic cholangial drainage (PTCD) or placement of biliary stents to reduce jaundice. All patients and their families were informed of the details and risks of the operation one day before surgery, and medical documents such as informed consent were signed.

Surgical procedure

PD is performed under laparoscopy, and five trocars are used as a "V" shape (Fig. 1). Digestive tract reconstruction is performed according to the Child method, which is composed sequentially of PJ, choledochojejunostomy, and gastrojejunostomy. Besides, Braun's jejunojejunostomy is performed routinely.

Chen's pancreaticojejunostomy

Chen's pancreatoenterostomy with a small jejunal opening and the stent insertion in the pancreatic duct is used in our center at present [13]. First, a stent corresponding to the diameter of MPD was inserted into the remnant pancreatic duct. Then, in the direction perpendicular to the longitudinal axis of the pancreas, three intermittent U-shaped stitches are placed on the cross-section of the pancreatic stump, and the middle stitch is used to fix the stent (Fig. 2.A). Subsequently, in the direction parallel to the longitudinal axis of the pancreas, approximately 1 cm away from the pancreatic section, the first suture penetrated the pancreas from the ventral to the dorsal side and inserted the posterior wall of the jejunum about 2 cm away from jejunum section. Then, this suture passed through the seromuscular layer of the intestinal wall from posterior to anterior. The needle was inserted 0.5 cm away from the margin of the pancreas section and penetrated the pancreatic stump for the second time from the dorsal to the ventral side. The suture then passed through the seromuscular layer of the anterior wall of the jejunum from posterior to anterior and was tied in a knot (Fig. 2.B). In this way, the U-shaped suture was completed. A small hole approximate to the MPD size was punctured at the jejunum wall opposite the duct of the pancreatic stump, and the rest of the stent was inserted into the jejunal lumen (Fig. 2.C). Depending on the width of the pancreatic stump, 5 to 6 U-shaped sutures were completed to make the jejunal wall form a C shape to wrap around the pancreatic stump (Fig. 2.D-E). The intraoperative procedures of Chen's pancreaticojejunostomy was shown in Fig. 3.

The remaining digestive tract reconstruction

Choledochojejunostomy was performed about 8 cm away from the PJ anastomosis. Next, antecolic gastrojejunostomy was performed in front of the colon about 50 cm away from the choledochojejunostomy anastomosis. Then, Braun's anastomosis [14] was performed about 15 cm away from the gastrojejunostomy anastomosis. After checking the surgical area in case of bleeding, drainage tubes were placed separately in front of and behind the PJ anastomosis and the choledochojejunostomy anastomosis.

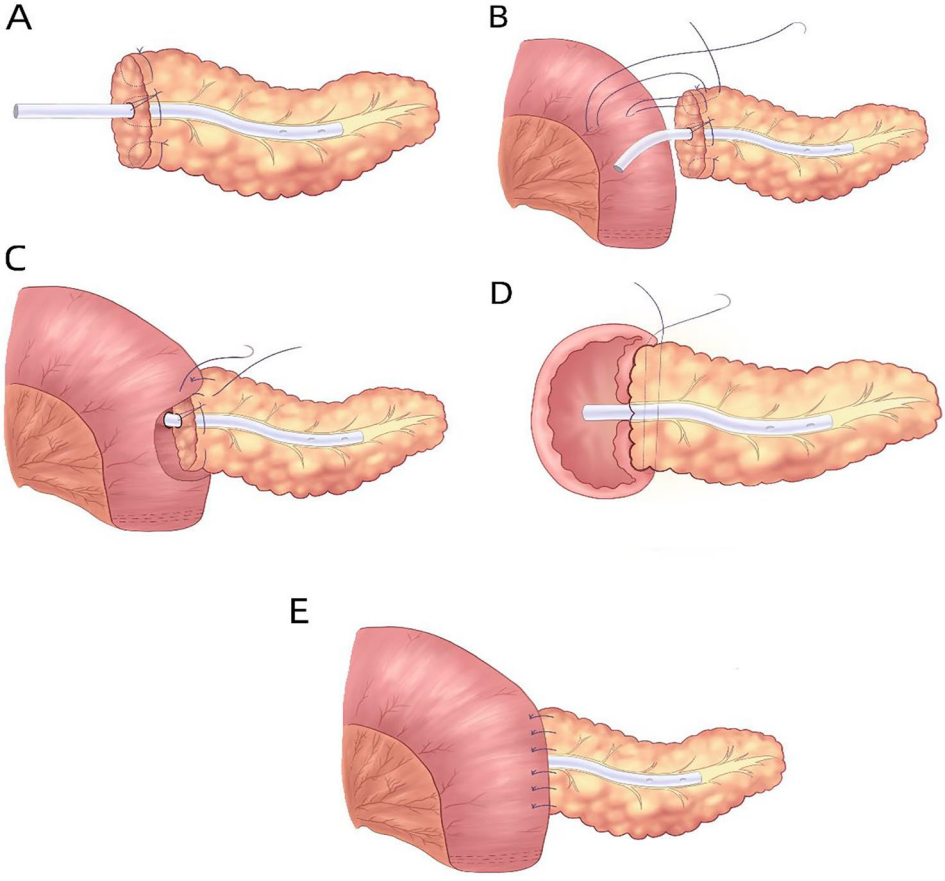

Fig. 2 Diagram of Chen's pancreaticojejunostomy. **A**. Pancreatic stump "U" suture **B**. Longitudinal "U" suture through the pancreas **C**. Placement of the rest of the pancreatic stent into the jejunum **D**. "C" shape of the jejunal wall to wrap around the pancreatic stump **E**. Schematic diagram of complete pancreaticojejunostomy

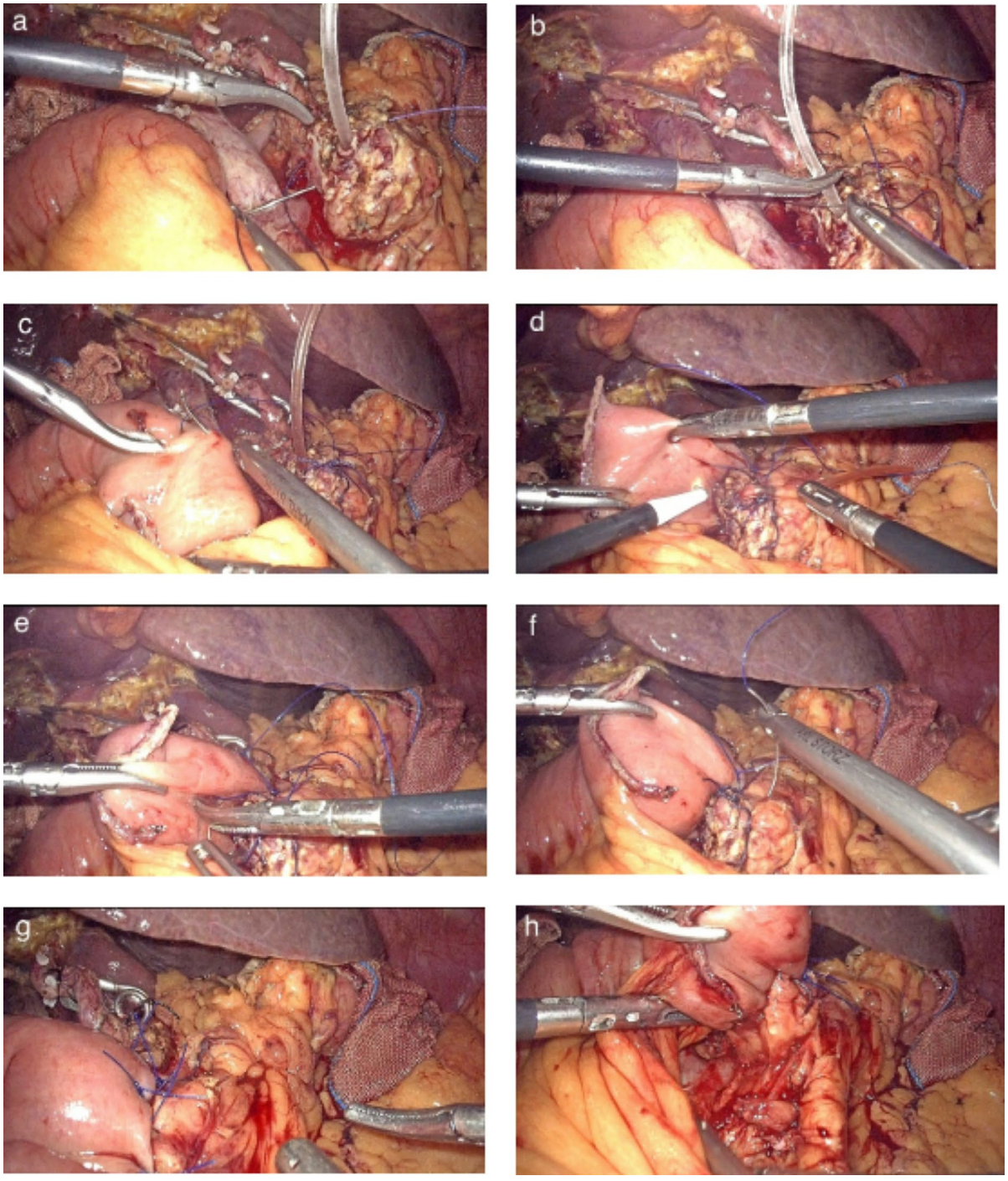

Fig. 3 Diagram of Chen's pancreaticojejunostomy. **a**. The pancreatic section was sutured in the U shape, and a stent was placed in the pancreatic duct. **b**. The middle stitch was fixed through the stent. **c**. Longitudinal U-shaped suture across the pancreas. **d**. A small hole is made in the jejunum corresponding to the pancreatic duct. **e**. The other end of the stent was inserted into the jejunum. **f**. The pancreatic stump was wrapped by the jejunum in a C-shaped. **g**. Front view. **h**. Back view

Perioperative variables and definitions

The baseline characteristics in this study include gender, age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, comorbidities, preoperative biliary drainage for jaundice reduction, total bilirubin, albumin, and alanine aminotransferase (ALT) levels within one week before surgery, lesion location, pancreatic texture, and main pancreatic duct diameter. Perioperative variables include surgical time, intraoperative blood loss, intraoperative blood transfusion,

postoperative pancreatic fistula, postoperative bleeding, delayed gastric emptying (DGE), bile leakage, other postoperative complications, incidence of reoperation, reoperation, and mortality within 90 days. The diameter of the main pancreatic duct (MPD) is obtained from preoperative CT images. The small MPD group is defined as having an MPD size of ≤ 3 mm, while the large MPD group has an MPD size of > 3 mm. The texture of the pancreas is determined and recorded by the surgeon as soft or not soft. Postoperative pancreatic fistula (POPF) is defined and graded according to the International Group on Pancreatic Fistula (ISGPF) [15]. Among them, if the amylase content in the drainage fluid exceeds three times the upper limit of normal serum amylase levels more than three days after pancreatic surgery, it is defined as biochemical leakage. Grade B and C pancreatic fistula are defined as POPF. Delayed gastric emptying [16] bile leakage [17]and postoperative hemorrhage [18] are determined based on previous reports. 112patients were divided patients into two groups according to pancreatic texture and the MPD size. Furthermore, risk factors for anastomoses in pancreatic surgeries were evaluated through the 4-teir classification system proposed by the International Study Group of Pancreatic Surgery (ISGPS) [19].

Table 1 Demographic and clinical characteristics of 112 patients

Variables		
Age, year, median (rage)	64	(46–80)
Gender		
Male, n (%)	61	(54.5%)
Female, n (%)	51	(45.5%)
BMI, kg/m^2	22	(17–33)
Hypertension, n (%)	45	(40.2%)
Diabetes, n (%)	15	(13.4%)
Smoking, n (%)	31	(27.7%)
Drinking, n (%)	24	(21.4%)
History of abdominal surgery, n (%)	29	(25.9%)
Preoperative biliary drainage, n (%)	51	(45.5%)
Total bilirubin, μmol/L	51.9	(5.5-230.5)
ALT, μ/L	54	(6.0-638.2)
Albumin, g/L	38.9	(27.7–48.4)
ASA class, n (%)		
I	9	(8.0%)
II	44	(39.3%)
III	57	(50.9%)
IV	2	(1.8%)
Lesion location, n (%)		
Pancreas	34	(30.4%)
Ampulla	16	(14.3%)
Bile duct	21	(18.8%)
Duodenum	41	(36.6%)
Pancreatic texture, n (%)		
Soft	45	(40.2%)
Not-soft	67	(59.8%)
MPD size, n (%)		
≤ 3 mm	41	(36.6%)
>3 mm	71	(63.4%)

BMI body mass index; *ALT* alanine aminotransferase; *ASA* American Society of Anesthesiologists; *MPD* main pancreatic duct

Statistical analysis

SPSS version 25.0 software was used for data analysis. Values were expressed as frequency (%) and median (range). Categorical data were analyzed by the Chi-square test or Fisher's exact test, and continuous data were analyzed by the Mann-Whitney *U* test. A *P* value less than 0.05 was considered statistically significant.

Results

Patient characteristics

The demographic and clinical characteristics of the patients are summarized in Table 1. 112 patients who underwent LPD were included in this study, consisting of 61 males and 51 females with a median age of 64 years old (46–80 years old). The median BMI of the patients was 22 kg/m2 (17–33 kg/m^2). In terms of comorbidities, 45 patients (40.2%) had hypertension, 15 patients (13.4%) had diabetes. In addition, 31 patients (27.7%) had a history of smoking, 24 (21.4%) had a history of alcohol consumption, 29 patients (15.9%) had a history of abdominal surgery, and 51 patients (45.5%) underwent preoperative biliary drainage. In terms of blood tests conducted within one week before surgery, the median preoperative total bilirubin was 51.9 μmol/L (6.0-638.2 μmol/L), median ALT was 54 U/L (6.0-638.2 U/L), and median albumin was 38.9 g/L (27.7–48.4 g/L). The most common lesion site is the pancreas, followed by the ampulla. In this study, 45 patients (40.2%) had soft pancreatic texture, and 41 patients (36.6%) had a small main pancreatic duct (diameter ≤ 3 mm).

Perioperative outcomes

The perioperative results are shown in Table 2. The median operation time was 300 min, the median PJ time was 27 min, the median intraoperative blood loss was 100 ml, and 16 patients (14.3%) received an intraoperative blood transfusion. According to the diagnostic criteria of ISGPF, there were 25 cases (22.3%) of biochemical leakage and eight cases (7.1%) of POPF, all classified as grade B POPF. Ten patients (8.9%) experienced postoperative hemorrhage, including six cases (5.4%) of abdominal hemorrhage and four cases (3.6%) of upper gastrointestinal hemorrhage. Among them, three patients underwent percutaneous abdominal angiography and selective arterial embolization, two patients underwent gastroscopy for hemostasis, one patient underwent laparotomy for hepatic artery suture hemostasis, three patients were cured after conservative treatment, and one case died

Table 2 Perioperative outcomes of 112 patients

Variables		
Operation time, min, median (range)	300	(220–600)
PJ time, min, median (range)	27	(16–40)
Intraoperative blood loss, ml, median (range)	100	(15–500)
Intraoperative transfusion, n (%)	16	(14.3%)
Biochemical leak, n (%)	25	(22.3%)
Pancreatic fistula, n (%)	8	(7.1%)
Grade B, n (%)	8	(7.1%)
Grade C, n (%)	0	NA
Postoperative hemorrhage, n (%)	10	(8.9%)
Intra-abdominal hemorrhage, n (%)	6	(5.4%)
Upper gastrointestinal hemorrhage, n (%)	4	(3.6%)
Delayed gastric emptying, n (%)	8	(7.1%)
Biliary fistula, n (%)	4	(3.6%)
Intra-abdominal infection, n (%)	8	(7.1%)
Pulmonary infection, n (%)	6	(5.4%)
Reoperation, n (%)	4	(3.6%)
Postoperative days in hospital, d, median (range)	16.5	(7–55)
90-day Death, n (%)	2	(1.8%)

PJ pancreaticojejunostomy; *POPF* postoperative pancreatic fistula

due to postoperative abdominal hemorrhage, considering injury to the right inferior phrenic artery during lymph node dissection. Eight patients (7.1%) experienced delayed gastric emptying, all of whom recovered after conservative treatment. Four patients (3.6%) experienced bile leakage. Two patients underwent laparotomy and were found ruptured choledochojejunostomy anastomosis, which was repaired by suturing. Two patients recovered after conservative treatment. Eight patients (7.1%) developed abdominal infections, and two patients were diagnosed with bile leakage. After exploratory laparotomy, the patients were cured by placing drainage tubes and antibiotics treatment. Two patients recovered after percutaneous puncture and catheterization drainage. Three patients were cured after conservative treatment, such as anti-infection and prolonged drainage. One case died after septic shock due to an abdominal infection caused by intestinal anastomosis fistula. Six patients (5.4%) developed pulmonary infections and were cured after antibiotic treatment. The median length of hospital stay was 16.5 days (7–55 days), and no patients died due to postoperative pancreatic fistula.

Clinical outcomes according to the pancreatic texture

112 patients were divided into two groups based on the texture of the pancreas, and the comparative outcomes are summarized in Table 3. There was no statistically significant difference between the two groups of patients in terms of gender, age, BMI, ASA score, previous abdominal surgery history, preoperative biliary drainage, reoperation rate, postoperative hospital stay, and postoperative 90-day mortality rate. The median surgical time and median PJ time in the soft pancreas group were longer than those in the not-soft pancreas group, but the difference was not significant ($P > 0.05$). The incidence of POPF in the soft pancreas group was higher than that in the not-soft pancreas group (11.1% vs. 4.5%), but the difference was not statistically significant ($P > 0.05$).

Clinical outcomes according to the MPD size

112 patients were divided into two groups based on the MPD size, and the clinical outcomes are summarized in Table 4. There were no significant statistical differences between the two groups in terms of demographics, underlying diseases, preoperative biliary drainage, median surgery time, median PJ time, reoperation rate, postoperative hospital stay, and 90-day death rate. The incidence of POPF in the small MPD group was higher than that in the large MPD group (9.8% vs. 5.6%), but the difference was not statistically significant ($P > 0.05$).

Comparison results of POPF based on the pancreatic texture and MPD size

According to the 4-teir classification system proposed by the ISGPS [19] there was no significant difference ($P > 0.05$) in the incidence of POPF among the four grades based on the pancreatic texture and the MPD size. The incidence rates of grades A-D were 4.7%, 4.2%, 7.1%, and 17.6% (Table 5).

Discussion

LPD is still a challenging and complex surgery, with pancreatic fistula being the most common, complicated, and dangerous postoperative complication [20, 21]. The soft texture of the pancreas and the small diameter of MPD (≤ 3 mm) increase the difficulty for surgeons to operate and incur the added risk of POPF [22]. Although numerous PJ anastomosis methods have been raised, none of them can completely avoid the occurrence of pancreatic fistula. At present, duct-to-mucosa anastomosis is a commonly used method for pancreatic intestinal reconstruction [5] achieving the continuity and patency between pancreatic duct and jejunal mucosa. However, precise and lightweight suturing is required for duct-to-mucosa anastomosis under laparoscopy, which is problematic for beginners to master. Especially with the soft pancreatic texture, undilated pancreatic duct, or thin pancreatic wall, unskilled suturing may cause pancreatic duct rupture and parenchymal tearing, which is arduous to repair and influences the quality of anastomosis, precipitating a higher incidence of POPF. The invaginated anastomosis is relatively simple to operate, but due to the exposure of the pancreatic stump to pancreatic juice and intestinal digestive juice, it can motivate pancreatic bleeding and necrosis or poor anastomotic healing, thus leading to POPF.

Table 3 Comparison between 112 patients with soft and not-soft pancreatic texture

Variables	Soft ($n=45$)	Not-soft ($n=67$)	*P*-value
Age, year, median (range)	62 (46–78)	64 (47–80)	0.637
Male, n (%)	27 (60%)	34 (50.7%)	0.335
BMI, kg/m^2, median (range)	22 (17–33)	22 (17–27)	0.827
Smoking, n (%)	16 (35.6%)	15 (22.5%)	0.127
Drinking, n (%)	13 (28.9%)	11 (16.4%)	0.115
Hypertension, n (%)	18 (40%)	27 (40.3%)	0.975
Diabetes, n (%)	7 (15.6%)	8 (11.9%)	0.582
History of abdominal surgery, n (%)	14 (31.1%)	15 (22.4%)	0.302
Preoperative biliary drainage, n (%)	19 (42.4%)	32 (47.8%)	0.564
Total bilirubin, μmol/L	45.3 (6-194.9)	57.8 (5.5-230.5)	0.420
ALT, μ/L	40.5 (6-638.2)	63 (6-441)	0.411
Albumin, g/L	37.7 (28.8–48.2)	39.1 (27.7–48.4)	0.245
ASA class, n (%)			0.445*
I	2 (4.4%)	7 (10.4%)	
II	17 (37.8%)	27 (40.3%)	
III	26 (57.8%)	31 (46.3%)	
IV	0	2 (3%)	
MPD size, n (%)			0.833
≤ 3 mm	17 (37.8%)	24 (35.8%)	
>3 mm	28 (62.2%)	43 (64.2%)	
Intraoperative transfusion, n (%)	5 (11.1%)	11 (16.4%)	0.431
Intraoperative blood loss, ml, median (range)	100 (50–500)	100 (15–500)	0.339
Operation time, min, median (range)	318 (220–600)	300 (220–440)	0.188
PJ time, min, median (range)	28 (19–40)	26 (16–39)	0.143
Biochemical leak, n (%)	11 (24.4%)	14 (20.9%)	0.658
POPF, n (%)	5 (11.1%)	3 (4.5%)	0.264*
Grade B, n (%)	5 (11.1%)	3 (4.5%)	0.264*
Grade C, n (%)	0	0	NA
Postoperative hemorrhage, n (%)	7 (15.6%)	3 (4.5%)	0.086*
Intra-abdominal hemorrhage, n (%)	4 (8.9%)	2 (3%)	0.217*
Upper gastrointestinal hemorrhage, n (%)	3 (6.7%)	1 (1.5%)	0.300*
Delayed gastric emptying, n (%)	3 (6.7%)	5 (7.5%)	1*
Biliary fistula, n (%)	2 (4.4%)	2 (3%)	1*
Intra-abdominal infection, n (%)	5 (11.1%)	3 (4.5%)	0.264*
Pulmonary infection, n (%)	3 (6.7%)	3 (4.5%)	0.683*
Reoperation, n (%)	3 (6.7%)	1 (1.5%)	0.300*
Postoperative days in hospital, d, median (range)	19 (10–54)	16 (7–55)	0.074
90-day Death, n (%)	1 (2.2%)	1 (1.5%)	1*

BMI body mass index; *ALT* alanine aminotransferase; *ASA* American Society of Anesthesiologists; *MPD* main pancreatic duct; *PJ* pancreaticojejunostomy; *POPF* postoperative pancreatic fistula. *Fisher's exact test

After Chen's pancreaticojejunostomy was proposed in 1995, this technology has been cumulatively applied in medical centers. The traditional Chen's pancreaticojejunostomy belongs to the category of invaginated anastomosis. After being improved by surgeons according to clinical practice, various forms of Chen's pancreaticojejunostomy have been derived, crossing the scope of invaginated anastomosis [12, 13]. In this study, Chen's pancreaticojejunostomy was performed with longitudinal U-shaped sutures that penetrated the entire pancreas twice. There is sufficient pancreatic tissue sutured with each stitch, which reduces the suture accuracy, weakens the tension and cutting effect of the suture on the pancreatic parenchyma [23] and reduces the risk of pancreatic tearing. With the small jejunal opening being accomplished [24] the pancreatic stump was wrapped by the jejunal serosa in a C-shape after the suture was tightened. The gap between the pancreatic stump and the jejunum wall was closed, which could prevent retention and leakage of pancreatic fluid, and reduce the risk of pancreatic cross-section bleeding. A stent tube was placed and fixed in accordance with the suitable diameter of the MPD, the other end of which was placed into the jejunal lumen, so that the pancreatic duct and intestinal mucosa

Table 4 Comparison between 112 patients with small (≤ 3 mm) and large (> 3 mm) MPD

Variables	Small MPD (*n* = 41)	Large MPD (*n* = 71)	*P*-value
Age, year, median (range)	65 (46–77)	63 (47–80)	0.597
Male, n (%)	21 (51.2%)	40 (56.3%)	0.600
BMI, kg/m^2, median (range)	22 (17–27)	22 (17–33)	0.224
Smoking, n (%)	13 (31.7%)	18 (25.4%)	0.469
Drinking, n (%)	12 (29.3%)	12 (16.9%)	0.124
Hypertension, n (%)	16 (39%)	29 (40.8%)	0.85
Diabetes, n (%)	3 (7.3%)	12 (16.9%)	0.151
History of abdominal surgery, n (%)	11 (26.8%)	18 (25.4%)	0.864
Preoperative biliary drainage, n (%)	23 (56.1%)	28 (39.4%)	0.088
Total bilirubin, μmol/L	44.3 (8.2-230.5)	55.7 (5.5-212.1)	0.679
ALT, μ/L	51 (8.8-638.2)	54 (6-441)	0.947
Albumin, g/L	39.1 (31.2–45.4)	38.6 (27.7–48.4)	0.239
ASA class, n (%)			0.226*
I	2 (4.9%)	7 (9.9%)	
II	18 (43.9%)	26 (36.6%)	
III	19 (46.3%)	38 (53.5%)	
IV	2 (4.9%)	0	
Pancreas texture, n (%)			0.833
Soft	17 (41.5%)	28 (39.4%)	
Not-soft	24 (58.5%)	43 (60.6%)	
Intraoperative transfusion, n (%)	7 (17.1%)	9 (12.7%)	0.522
Intraoperative blood loss, ml, median (range)	100 (20–500)	100 (15–500)	0.750
Operation time, min, median (range)	300 (220–600)	300 (220–411)	0.628
PJ time, min, median (range)	27 (18–40)	27 (16–39)	0.846
Biochemical leak, n (%)	12 (29.3%)	13 (18.3%)	0.180
POPF, n (%)	4 (9.8%)	4 (5.6%)	0.461*
Grade B, n (%)	4 (9.8%)	4 (5.6%)	0.461*
Grade C, n (%)	0	0	NA
Postoperative hemorrhage, n (%)	4 (9.8%)	6 (8.5%)	1*
Intra-abdominal hemorrhage, n (%)	2 (4.9%)	4 (5.6%)	1*
Upper gastrointestinal hemorrhage, n (%)	2 (4.9%)	2 (2.8%)	0.623*
Delayed gastric emptying, n (%)	5 (12.2%)	3 (4.2%)	0.140*
Biliary fistula, n (%)	3 (7.3%)	1 (1.4%)	0.138*
Intra-abdominal infection, n (%)	4 (9.8%)	4 (5.6%)	0.461*
Pulmonary infection, n (%)	4 (9.8%)	2 (2.8%)	0.189*
Reoperation, n (%)	2 (4.9%)	2 (2.8%)	0.623*
Postoperative days in hospital, d, median (range)	18 (7–55)	16 (9–54)	0.521
90-day Death, n (%)	0	2 (2.8%)	0.532*

BMI body mass index; *ALT* alanine aminotransferase; *ASA* American Society of Anesthesiologists; *PJ* pancreaticojejunostomy; *POPF* postoperative pancreatic fistula.
*Fisher's exact test

are connected through the stent tube, promoting faster healing of the anastomose [25, 26]. Consequently, Chen's pancreaticojejunostomy does not require precise suturing, making it easy for beginners to operate and highly reproducible.

In this study, the incidence of biochemical leakage was 22.3%, the incidence of B-grade pancreatic fistula was 7.1%, and there was no C-grade pancreatic fistula. The incidence of POPF was lower than some current research reports [27]indicating that laparoscopic use of Chen's pancreaticojejunostomy can effectively reduce the incidence of POPF. After grouping according to pancreatic texture, pancreatic duct diameter, and the four-teir classification system of ISGPS, the intergroup difference was not statistically significant in the incidence of POPF ($P > 0.05$), indicating that this anastomosis method can achieve good results in diverse conditions of pancreatic textures and MPD sizes.

It is worth noting in this study that some patients defined as having grade B pancreatic fistula did not develop relevant clinical symptoms, simply because the drainage tube was placed for more than 21 days, similar to having biochemical leakage. These patients usually receive conservative treatment and extend the retention

Table 5 Comparison results of POPF based on pancreatic texture and main pancreatic duct size in 112 patients

Variable	Patients without POPF	Patients With POPF	Rate	*P*-value
A. Not-soft pancreatic texture and MPD > 3 mm	41	2	4.7%	1[*a]
B. Not-soft pancreatic texture and MPD ≤ 3 mm	23	1	4.2%	0.290[*b]
C. Soft pancreatic texture and MPD > 3 mm	26	2	7.1%	0.350[*c]
D. Soft pancreatic texture and MPD ≤ 3 mm	14	3	17.6%	
Total	104	8	7.1%	

POPF postoperative pancreatic fistula; *MPD* main pancreatic duct. *Fisher's exact test; [a] A vs. B; [b] B vs. D; [c] C vs. D

time of drainage tubes, which increases the incidence of grade B pancreatic fistula. Current research suggests that delaying the removal of drainage tubes may promote the development of POPF-related complications [28, 29] as drainage may lead to mechanical corrosion of soft tissues and blood vessels by pancreatic enzymes. In this study, postoperative hemorrhage occurred in 8.9% of patients, and there are four cases probably associated with POPF, including one case of intra-abdominal hemorrhage and three cases of upper gastrointestinal hemorrhage, which is probably related to Chen's pancreaticojejunostomy technique. We used to use the classic Chen's U-shaped suture, in which the length of the intestinal incision is consistent with the width of the pancreatic stump. We believe that exposure of the pancreatic stump to the intestinal fluid may lead to bleeding. Based on this consideration, we reduced the incision of the intestine to the size of the pancreatic duct in 2021, which still belongs to the category of Chen's pancreaticojejunostomy and is adopted by many surgeons.

Besides, retrograde and ectopic bacteria can invade the anastomose area by prolonging drainage time, causing infection, bleeding, or anastomotic rupture. Therefore, if the conservative postoperative drainage tube management strategy is changed, the incidence of POPF in our center will decrease. In addition, the use of intermittent suturing currently raises the difficulty of laparoscopic knotting and extends the time of PJ anastomosis. We have attempted to use continuous suturing, which can greatly shorten the time of pancreatic intestinal anastomosis. If the surgical team cooperates proficiently, it can be completed efficiently and ensure the quality of anastomosis. Studies have shown that in open and minimally invasive surgeries, continuous suturing is safer and faster compared to intermittent suturing, and can reduce the risk of POPF occurrence [30–33]. So, if continuous suturing is used, the postoperative effect is ideal.

Another noteworthy aspect is that Chen's pancreaticojejunostomy involves the intermittent U-shaped suture of the pancreatic stump to avoid the possibility of pancreatic fistula and delayed bleeding in the pancreatic section, in case of the following situations: there are openings of the accessory pancreatic duct or small lobular ducts in the pancreatic stump, and branches of the dorsal pancreatic artery. However, this step has some drawbacks, including prolonged PJ time and high requirements for knot tightness. If the suture is too tight, the pancreatic stump may become ischemic, and for soft pancreatic stump, pancreatic juice may seep out from the suture needle hole. Anbang Zhao et al. reported a method of duct-to-mucosa anastomosis, using intermittent anastomosis between the pancreas and jejunum. This method does not specifically suture the section of the pancreatic stump, resulting in short anastomosis time and a low incidence of POPF [34]. As the pancreatic stump was wrapped by the jejunal serosa in a C-shape after the longitudinal U-shaped suture was tightened in Chen's pancreaticojejunostomy, this step can also prevent postoperative pancreatic fistula and bleeding. Therefore, we concept that by reducing the number of suture needles or not suturing the pancreatic stump during Chen's pancreaticojejunostomy, the operative time can be shortened and operational steps can be further simplified. However, this clinical effect requires further research in our center.

There are studies indicating that stent placement has the potential to prevent POPF in patients with undilated pancreatic ducts [26, 35, 36]. Currently, our center routinely performs pancreatic duct stent placement in PJ. We have used central venous catheters and epidural catheters as the main pancreatic duct support tubes, but these materials have few sizes and high costs. At present, our center chooses ureteral catheter as the supporting tube material. The catheter comes in various sizes, is cost-effective, and has a soft and elastic texture that will not cause mechanical damage to nearby tissues. We have not found any phenomenon of gastrointestinal perforation caused by the detachment of this type of support tube in our center, so this material provides a new option for pancreatic duct support tubes, and its safety and effectiveness need further research and verification.

Due to the retrospective nature of this study, there are some limitations, including a small sample size, single-center study, and inherent selection bias. In order to further verify the safety and effectiveness of this anastomosis technique in difficult situations of the soft pancreas and small MPD size (≤ 3 mm), it is expected to conduct larger sample size multicenter controlled trials in the future.

Conclusions

In summary, Chen's pancreaticojejunostomy is a safe and simple anastomosis technique, which is reliable under the condition of the soft pancreatic texture or small MPD size (≤ 3 mm). As this is a single-center retrospective study, it is necessary to conduct randomized controlled studies with larger sample size to support the results of this study.

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None.

Author contributions
Zhu Y and Yu J collected and analyzed clinical data, and wrote the the main manuscript text; Li XY, Wang HB, Sun HP managed the patients and collected clinical data; Chen YJ revised the manuscript; Li XG, Liao XF designed this study and revised the manuscript. All authors reiewed and approved the final manuscript.

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Data availability
The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Medical Ethics Committee of Xiangyang Central Hospital Affiliated to Hubei University of Arts and Sciences (No.2024-010). As this was a retrospective study, informed consents from patients were not required.

Competing interests
The authors declare no competing interests.

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