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ORIGINAL ARTICLE

A comparative study of end-to-end pancreatic anastomosis versus pancreaticojejunostomy after robotic central pancreatectomy

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Abstract

Robotic central pancreatectomy has been applied for 20 years with the advantage of minimally invasive surgery. The general pancreatic reconstruction approaches include pancreaticojejunostomy and pancreaticogastrostomy. Recently, our group reported a few preliminary cases of application of end-to-end pancreatic anastomosis in robotic central pancreatectomy. This novel approach has not been compared with the conventional approach on a large scale. The objective of this study is to compare end-to-end pancreatic anastomosis with pancreaticojejunostomy after robotic central pancreatectomy based on the perioperative and long-term outcomes. Clinical data consist of demographics, clinicopathologic characteristics, perioperative and long-term outcomes of patients who underwent robotic central pancreatectomy from March 2015 to December 2019 were collected and analyzed. Seventy-four patients received a robotic central pancreatectomy with either end-to-end pancreatic anastomosis ($n=52$) or pancreaticojejunostomy ($n=22$). End-to-end pancreatic anastomosis was associated with shorter operative time and reduced blood loss. Despite a higher incidence of clinically relevant postoperative pancreatic fistula (69.2% vs. 36.4%, $p=0.009$), the newer anastomotic technique was also associated with earlier removal of nasogastric tube and resumption of oral intake. Long-term results, in terms of either endocrine or exocrine function, were not affected by the anastomotic technique. We have shown the feasibility of robotic central pancreatectomy with end-to-end pancreatic anastomosis. Despite streamlined technique, the newer anastomosis appears to improve early post-operative results while preserving endocrine and exocrine functions in the long-term period. Evaluation of the true potential of robotic central pancreatectomy with end-to-end pancreatic anastomosis requires a prospective and randomized study enrolling a large number of patients.

Keywords Robotic surgery · Central pancreatectomy · Pancreaticojejunostomy · End-to-end pancreatic anastomosis

Introduction

Since the first open central pancreatectomy was performed in 1900s, various attempts have been made to improve this procedure [1]. In 1957, a double digestive anastomosis of the two pancreatic stumps to an omega-shaped jejunal loop after central pancreatectomy was carried out, and in 1984 the central pancreatectomy with pancreaticojejunostomy was reported [2, 3]. In the minimally invasive era, laparoscopic surgery has also been applied in central pancreatectomy [4]. However, inherent drawbacks of the laparoscopic surgery such as the fulcrum effects and inferior ergonomics have inhibited the development of laparoscopic central pancreatectomy. The development of the robotic-assisted surgical system enabled the advanced minimally invasive surgical system, which has shown many advantages. The delicate movements of the robotic instruments and the 3-dimentional magnified views facilitate the complex dissection and anastomosis in pancreatic surgeries. Up to date, some pancreatic surgical centers have reported their experience in robotic central pancreatectomy, using mainly pancreaticojejnuostomy or pancreaticogastrostomy for digestive reconstruction [5–8]. However, both anastomotic techiques are associated with frequent occurrence of complications, thus leaving

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room for significant improvement of surgical outcomes. According to the literature, the complication rate and the postoperative pancreatic fistula (POPF) rate of the central pancreatectomy were higher than those of the pancreaticoduodenectomy and distal pancreatectomy, and no significant difference was observed regarding the POPF between the pancreaticojejunostomy and pancreaticogastrostomy [9, 10].

Our center started to perform the robotic-assisted central pancreatectomy in 2015 and routinely applied the pancreaticojejunostomy in the beginning. To make full use of robotic-assisted surgical system, we have innovatively performed the robotic-assisted central pancreatectomy with end-to-end anastomosis, which was named robotic Rong's central pancreatectomy. In the robotic Rong's central pancreatectomy, two pancreatic stumps were anastomosed in an end-to-end fashion with the advantage that the digestive tract was not changed. According to our previous preliminary study, this procedure was safe and feasible for the benign and low-malignant potential neoplasms located in the neck and proximal body of the pancreas [11]. However, there has been no direct comparison between robotic central pancreatectomy with end-to-end pancreatic anastomosis and robotic central pancreatectomy with pancreaticojejunostomy. In this study, we provide, for the first time, this comparison.

Methods

Patients

The medical records of consecutive patients who underwent robotic central pancreatectomy in the "Department of HPB Surgical Oncology, the First Medical Center, Chinese PLA General Hospital" from March 2015 to December 2019 were analyzed retrospectively. Computed tomography (CT) or magnetic resonance imaging (MRI) or endoscopic ultrasonography and/or positron emission tomography-computed tomography (PET-CT) were performed before the operation. Based on the medical imaging, the surgical team made the diagnosis, evaluated the size and location of the lesion and its relationship with the main pancreatic duct and vessels. The operative plan was made according to the general inclusion criteria: (1) tumor located in the neck or the proximal body of the pancreas, (2) tumor closed to the main pancreatic duct and not suitable for enucleation, (3) the preoperative medical imaging indicated that the tumor was benign or low-malignant potential and the surgical candidates for pancreatic cystic neoplasm referred to the guideline for the diagnosis and treatment of pancreatic cystic neoplasms in China [12] (4) the estimated remnant distal pancreas larger than 5 cm, (5) tumor without vascular invasion, and (6) for the robotic Rong's central pancreatectomy, an estimated defect of the main pancreatic duct ≤ 5 cm after central pancreatectomy was also required.

Written consent was obtained from the patients before the surgery.

The following clinical data were collected: sex, age, body weight and high, tumor mass diameter, operative time, intraoperative blood loss, pathologic diagnosis, postoperative complications, length of hospital stay, condition of diabetes mellitus and chronic diarrhea. The patients were followed up by outpatient clinic interview and telephone.

Surgical techniques

All of the surgeries were performed by the same surgical team with extensive experience on robotic pancreatic surgery using the da Vinci robotic Surgical System, model Si (Intuitive Surgical, Sunnyvale, CA). The general surgical techniques were described as follows.

The patient was placed in a reverse Trendelenburg position with legs separated. Five trocars were used. After the abdominal exploration, the gastrocolic ligament was cut open. The inferior and superior margin of the pancreatic neck and body were carefully dissected to expose the superior mesenteric and portal veins. Afterwards, a post-pancreatic tunnel was created. The intraoperative ultrasonography was routinely used to confirm the location of the tumor and decide the transection line. During the transection process, the ultrasound scalpel or electrocoagulation hook was used, and attention should be paid to minimize the damage to the main pancreatic duct. The main pancreatic duct was cut with cold scissors to ensure good blood supply and prevent postoperative scarring stenosis.

In the conventional robotic central pancreatectomy, the central pancreas was resected by two approaches. In the first approach, ultrasound scalpel or electrocoagulation hook was used to cut the pancreatic parenchyma, and the proximal stump of the pancreas was sewed by 4–0 polypropylene suture (Prolene™, Ethicon, New Jersey, USA). Alternatively, the central pancreas could be transected by a linear cutting stapler. The pancreatic parenchyma should be squeeze adequately by the cartridge before firing.

Pancreatic reconstruction in the robotic Rong's central pancreatectomy

As we previously reported, the two pancreatic stumps were sufficiently mobilized from the posterior tissues. A silicone pancreatic duct stent was placed into two stumps of the main pancreatic duct and fixed with a distal stump with 5–0 absorbable suture (PDS-II™, Ethicon, New Jersey, USA). For pancreatic duct stent, we chose to use silicone tube, usually silicone ureter (8Fr–12Fr), or hospital-made silicone pancreatic duct stent (in three sizes, 0.8 mm, 1.2 mm and

1.5 mm in diameter). Next, two or three (depending on the size of pancreatic stump) figure-of-eight or-U sutures by 4–0 polypropylene suture (Prolene™, Ethicon, New Jersey, USA) was made to reinforce the two pancreatic stumps. Finally, an end-to-end anastomosis of the two pancreatic stumps were performed with 4–0 polypropylene suture (Prolene™, Ethicon, New Jersey, USA), either by continuous suturing of the anterior and posterior layers of the two pancreatic stumps or by Blumgart penetrating suture, at the surgeon's discretion. The stent was continuously inserted toward the proximal duct stump while tightening the sutures [11].

Pancreatic reconstruction in the conventional robotic central pancreatectomy

The method of the pancreaticojejunostomy was nearly the same as the pancreaticoduodenectomy. The jejunum was transected about 15 cm away from the Treitz ligament. A two-layer or single-layer coutinuous end-to-side pancreaticojejunostomy was performed with 4–0 Prolene sutures. An internal pancreatic ductal stent was inserted in the distal pancreatic duct remnant and jejunal lumen [13, 14].

Finally, two drains were placed on each of the upper and lower margins of the anastomosis site.

Definition of POPF

The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula was used to grade POPF[15].

Grading of postoperative complications

The Clavien-Dindo classification was used for grading postoperative complications [16].

Postoperative care

After the surgery, intravenous antibiotics, total parenteral nutrition, analgesic, somatostatin, proton pump inhibitors were routinely used. The nasogastric tube was usually removed in postoperative day 1–3 and then a fluid diet was given. The amylase level of the drainage fluid was tested in postoperative day 1, 3 and 5. The ultrasonography or computerized tomography was obtained in postoperative day 5 to find possible fluid accumulation. The drainage tube was removed if there is no evidence of POPF and the volume of drainage fluid is less than 10 mL/day. For patients with POPF who retained the drainage tube for a long time, the drainage tube was intermittent retracted as the volume of drainage decreased.

Statistical analysis

The data were presented as frequency (proportion) for categorical variables and mean ± standard deviation (SD) or medians (interquartile range, IQR) for continuous variables as appropriate based on normality. Statistical analysis was conducted using SPSS 24.0 (IBM Corp, New York, USA) and GraphPad Prism 7.0 (GraphPad Software, San Diego, USA). The Differences between the two groups were analyzed using the Chi squared test for categorical variables, and the one-way analysis of variance or nonparametric tests for continuous variables as appropriate based on normality. A p value of < 0.05 was considered statistically significant.

Results

Demographic characteristics

During the study period, a total of 79 patients received a robotic central pancreatectomy. Excluding four patients who underwent pancreaticogastrostomy for digestive reconstruction and one patient who underwent the pancreatic tumor enucleation concurrent with the central pancreatectomy for two lesions, 74 patients remained in who a direct end-to-end pancreatic anastomosis ($n = 52$, Rong's group) and a pancreaticojejunostomy ($n = 22$, PJ group) were performed. Since August 2017, the majority of the robotic central pancreatectomy was performed with Rong's approach. The demographic characteristics of these patients are shown in Table 1. No significant difference between the two groups was observed in the baseline demographic variables including sex, age, BMI, perioperative diabetes mellitus, ASA score, and size and pathology of tumors. The median tumor size was 2.4 cm (IQR 2.0–3.3) in the Rong's group and 2.4 cm (IQR 2.0–4.1) in the PJ group. The pathological diagnosis of the tumor was mainly intraductal papillary mucinous neoplasm (IPMN) (36.5%), serous cystadenoma (SCN) (32.7%) and neuroendocrine tumor (NET) (9.6%) in the Rong's group, and IPMN (36.4%), SCN (27.3%), NET (13.6%) and solid pseudopapillary tumor (SPT) (13.6%) in the PJ group. In Rong's group, a case of lipoma and a case of kidney cancer metastasis was diagnosed. The lipoma is benign and quite rare in the pancreas. This patient had recurrent acute pancreatitis and the MRI showed a suspicious lipoma close to the main pancreatic duct, which resulted in the decision of surgery.

Perioperative outcomes

The intraoperative parameters and postoperative outcomes were summarized in Table 2. The mean operative time for Rong's group and PJ group were 136.7 ± 24.9 min

Table 1 The clinicopathological characteristics of patients

	Rong's group $N=52$	PJ group $N=22$	p value
Sex			0.886
Female *n* (%)	34 (65.4)	14 (63.6)	
Male *n* (%)	18 (34.6)	8 (36.4)	
Age, median (IQR), years	49 (38, 60)	45 (23, 57)	0.425
BMI, mean ± SD,kg/m^2	24.1 ± 3.8	24.8 ± 3.8	0.505
Preoperative diabetes mellitus, *n* (%)	8 (15.4)	3 (13.6)	1.000
ASA			0.934
I, *n* (%)	4 (7.7)	2 (9.1)	
II, *n* (%)	46 (88.5)	19 (86.4)	
III, *n* (%)	2 (3.8)	1 (4.5)	
Tumor size, median (IQR), cm	2.4 (2.0, 3.3)	2.4 (2.0, 4.1)	0.766
Pathology			0.744
SCN, *n* (%)	17 (32.7)	6 (27.3)	
MCN, *n* (%)	4 (7.7)	2 (9.1)	
SPT, *n* (%)	3 (5.8)	3 (13.6)	
IPMN, *n* (%)	19 (36.5)	8 (36.4)	
NET, *n* (%)	5 (9.6)	3 (13.6)	
Kidney cancer metastasis, *n* (%)	1 (1.9)	0 (0.0)	
Mass-forming pancreatitis, *n* (%)	2 (3.8)	0 (0.0)	
Lipoma, *n* (%)	1 (1.9)	0 (0.0)	

and 195.1 ± 45.6 min ($p < 0.001$), respectively. The median estimated blood loss for Rong's and PJ group were 50 ml (IQR 35–50) and 100 ml (IQR 50–100) ($p < 0.001$), respectively. The mean size of the resected central pancreas in Rong's group was smaller than that of the PJ group (4.3 ± 1.0 vs. 5.3 ± 1.6 cm, $p = 0.017$). The median postoperative hospital stays for the Rong's and PJ group were 6 days (IQR 5–7) and 10 days (IQR 8–11) ($p < 0.001$), respectively. No intraoperative blood transfusion was needed in each group. One open conversion occurred in the PJ group because of the massive adhesion. The time to remove the nasogastric tube and oral intake of the Rong's group were significantly shorter than the PJ group (1 day [IQR 1–1] vs. 3 days [IQR 2–4], $p < 0.001$). The median drain removal time of Rong's group was significantly longer than that of the PJ group (50 days [IQR 20–72] vs. 18 days [IQR 16–54], $p = 0.007$) and Rong's group had more grade B POPF than PJ group (69.2% vs. 36.4%, $p = 0.009$).

One patient developed postoperative intraabdominal bleeding in the PJ group and was cured by drug conservative treatment. Three patients (5.8%) in the Rong's group received percutaneous puncture and drainage because of intraabdominal fluid accumulation. And five patients (9.6%) in Rong's group developed asymptomatic pancreatic pseudocyst. One patient with abdominal infection in the Rong's group and one patient with acute pancreatitis in the PJ group readmitted within postoperative 30 days, and recovered by conservative drug treatments.

The Rong's group had more grade 1 complication than that of the PJ group (53.8% vs. 31.8%), and the complication grades 3a or worse of the two groups were similar (5.8% vs. 0%, $p = 0.550$). The patient who developed the Grade 3a complication had intraabdominal accumulation and underwent percutaneous puncture and drainage. No patient underwent reoperation and postoperative 90 days mortality was not observed in each group.

The follow-up period were 684 and 1259 days in the Rong's and PJ group, respectively ($p < 0.001$). In terms of the long-term outcome, the exocrine and endocrine functions of the two groups were in the same order of magnitude during the follow-up period. 7.6% of the Rong's group and 4.5% in the PJ group developed new-onset or aggravated diabetes mellitus, respectively ($p = 1.000$). 1.9% of the Rong's group and 4.5% in the PJ group had chronic steatorrhea, respectively ($p = 0.509$).

Discussion

The development of medical imaging technology and the public's increasing awareness of health screening enabled early-stage detection of smaller, presumably benign, and asymptomatic pancreatic tumors. These tumors include pancreatic cystic neoplasms and neuroendocrine tumors, which can be treated with surgical treatment. In the current study, the SCN was the second most common tumor type in each group, although SCN was a benign tumor and does

Table 2 Intraoperative and postoperative outcomes

	Rong's group $N=52$	PJ group $N=22$	p value
Operative time, mean ± SD, min	136.7 ± 24.9	195.1 ± 45.6	**< 0.001***
Estimated blood loss, median (IQR), ml	50 (35, 50)	100 (50, 100)	**< 0.001***
Size of resected central pancreas, mean ± SD, cm	4.3 ± 1.0	5.3 ± 1.6	**0.020***
Intraoperative transfusion, *n* (%)	0 (0.0)	0 (0.0)	–
Open conversion, *n* (%)	0 (0.0)	1(4.5)	0.297
Nasogastric tube removal time, median (IQR), day	1 (1, 1)	3 (2, 4)	**< 0.001***
Time to oral intake, median (IQR), day	2 (2, 3)	4(3, 5)	**< 0.001***
Postoperative hospital stays, median (IQR), day	6 (5, 7)	10 (8, 11)	**< 0.001***
Overall complications (Clavien–Dindo grade)			**0.033***
1, *n* (%)	28 (53.8)	7 (31.8)	
2, *n* (%)	5 (9.6)	2 (9.1)	
3a, *n* (%)	3 (5.8)	0 (0.0)	
Clavien–Dindo 3a or worse, *n* (%)	3 (5.8)	0 (0.0)	0.550
POPF (2016 ISGPS definition and grading)			**0.009***
Biochemical leak, *n* (%)	16 (30.8)	14 (63.9)	
Grade B, *n* (%)	36 (69.2)	8 (36.4)	
Grade C, *n* (%)	0 (0.0)	0 (0.0)	
Postoperative Intraabdominal bleeding, *n* (%)	0 (0.0)	1 (4.5)	0.297
Postoperative pancreatitis, *n* (%)	3 (5.8)	1 (4.5)	1.000
Postoperative abdominal infection, *n* (%)	2 (3.8)	1 (4.5)	1.000
Pancreatic pseudocyst, *n* (%)	5 (9.6)	1 (4.5)	0.662
Percutaneous puncture and drainage, *n* (%)	3 (5.8)	0 (0.0)	0.550
Drain removal time, median (IQR), day	50 (20, 72)	18 (16, 54)	**0.007***
Readmission in postoperative 30 days, *n* (%)	1 (1.9)	1 (4.8)	0.495
Mortality in postoperative 90 days, *n* (%)	0 (0.0)	0 (0.0)	–
Follow-up period, median (range), day	684 (486, 844)	1259 (1095, 1461)	**< 0.001***
New-onset of diabetes mellitus, *n* (%)	2 (3.8)	0 (0.0)	1.000
Aggravated of diabetes mellitus diagnosed preoperatively, *n* (%)	2 (3.8)	1 (4.5)	1.000
Chronic steatorrhea, *n* (%)	1 (1.9)	1 (4.5)	0.510

not need to be resected unless symptomatic or appearing malignant features. According to a study by the European Study Group on Cystic Tumors of the Pancreas, 60% of the surgical indications for SCN were of uncertain diagnosis, 23% with symptoms, 12% with size increase (12%) [17]. In our clinical routine, SCN with small tumor size or atypical morphology was sometimes difficult to differentiate from MCN. Therefore, enucleation and segmental pancreatectomy were the preferred surgical procedures for these types of tumor. When the tumor was in close proximity to the main pancreatic duct or when the tumor was large, pancreatic enucleation was no longer suggested, and central pancreatectomy became the best option. The goal of the central pancreatectomy was to completely remove the lesion with better preservation of normal pancreatic tissue to the maximum amount, thus better preserve the endocrine and exocrine functions of the pancreas. Various studies have demonstrated the advantages of central pancreatectomy in the preservation of pancreatic endocrine and exocrine functions, however, a high morbidity rate was observed in this procedure [9, 18–20].

As abdominal surgery evolved from open to minimally invasive surgery, central pancreatectomy also moved into the era of robotic-assisted surgery. Similar to the open approach, the main-stream reconstruction approaches of robotic central pancreatectomy were pancreatojejunostomy and pancreatogastrostomy [5, 7, 8, 21]. Up to now, the largest single-center study of robotic central pancreatectomy was reported by Shi et al. [22], which compared a total of 110 cases of robotic central pancreatectomy and 60 open central pancreatectomy. Their results showed that the robotic central pancreatectomy had decreased operation time and decreased blood loss, whereas the complications including clinical relevant POPF, hemorrhage and abdominal infection were similar in the two groups [22]. However, the pancreatic reconstruction approach was different, and pancreatojejunostomy and pancreatogastrostomy were applied in the robotic and open group,

respectively. Our surgical team accomplished the 1000th case of robotic hepatopancreatobiliary surgery in Dec. 2016, the 2000th in Mar. 2018, 3000th in Jan. 2019 and 4000th in Mar. 2000, and accomplished the 1000th case of robotic pancreatic surgery in Sep. 2017 [23]. In our initial stage of performing the robot central pancreatectomy, a reconstruction approach of pancreatojejunostomy was applied, which was considered as the most complex procedure in the pancreatic surgery. Since Aug. 2017, the majority of robotic central pancreatectomy in our center were performed with an end-to-end pancreatic anastomosis. By this simple reconstruction technique and with the accumulation of experience in robotic pancreatic surgery, it was demonstrated in this study that the perioperative outcomes such as operative time, intraoperative blood loss, and postoperative recovery were significantly improved.

In robotic Rong's central pancreatectomy, two pancreatic cutting surfaces and the main pancreatic duct were connected by a pancreatic duct stent. In contrast, in the conventional central pancreatectomy, the proximal stump of the pancreas was completely sutured, and the POPF rate after robotic Rong's central pancreatectomy was theoretically higher than that of conventional pancreatectomy. Data from the present study showed that Rong's group had a higher rate of grade B pancreatic fistula than the PJ group. These grade B POPF were mainly due to the delayed removal of drainage tubes. After prolonged drain extraction, the majority were able to heal spontaneously, with only three cases of re-puncture to drain the abdominal fluid. Despite a large number of postoperative grade B pancreatic fistulas, no postoperative bleeding and no grade C pancreatic fistulas were observed in Rong's group, which can be attributed to that the gastrointestinal tract was integrity and the leaking pancreatic enzymes were not activated. Note that one postoperative intrabdominal hemorrhage occurred in the PJ group, which may be caused by the erosion of active pancreatic enzyme. Similarly, patients in the Rong's group were discharged from the hospital soon after surgery when the gastric tube was removed and oral intake started. Due to the reality of limited medical resources in China, many patients chose to return to their hometowns to recuperate, and the hospitals in their hometowns are prudent to handle the drainage tube, although we recommend to remove the drain after a telephone or online consultation. As a result, the tube was generally retained for a longer period of time than expected. In addition, our surgical team tended to keep the drainage tube in the position for a longer period to observe the drainage fluid, since we were in the preliminary stage of robotic Rong's procedure. In Rong's group, 9.6% of patients developed pancreatic pseudocysts after surgery, which was associated with early removal of the tube or poor drainage. During follow-up, these pseudocysts had no concomitant clinical symptoms, and the size of the pseudocysts remained stable or decreased. It should be addressed during further follow-up.

In this study, the pathological results demonstrated that nearly 30% of the lesions were diagnosed as serous cystadenoma (32.7% and 27.3% in Rong's group and PJ group, respectively). Pancreatic mucinous and serous cystadenoma accounted for a large proportion of pancreatic cystic diseases, and it was difficult to make a clear diagnosis before operation when the cystadenoma was in a small size. We chose the patients suitable for operation according to the clinical guideline of pancreatic cystic diseases in China [12]. Usually, When neoplasm is larger than 3 cm, the surgery is considered, which may be related to the increasing surgical risks and severer clinical symptoms along with the increasing tumor size. However, if the diagnosis of a serous cystadenoma was clear and there was no symptom, regular observation could be considered. Besides, neoplasms smaller than 3 cm showed clinical symptoms or could not be excluded from pancreatic neuroendocrine neoplasms or other neoplasms with malignant potential (mucinous cystadenoma, solid pseudopaillary neoplasm, intraductal papillary mucinous neoplasm, et al.) are also candidates for surgery. In addition, the mean size of the resected central pancreas in the Rong's group was smaller than that of the PJ group (4.3 vs. 5.3 cm, $p = 0.017$). It seemed that patients were divided into two groups based on the size of the pancreatic gap. Actually, PJ group and Rong's group have identical inclusion criteria for the patients with central pancreatectomy. Since this study was retrospective in its nature, before August 2017, we reconstructed the pancreas using the PJ method and afterwards using Rong's Procedure. The difference in tumor volume may have some effects on the extent of the central pancreatectomy, but the effect on the postoperative recovery is small given that the surgeries were performed by the same group members.

With regard to the long-term outcomes after pancreatectomy, the endocrine and exocrine functions of the pancreas are of great importance. As parenchyma-preserving surgery, the role of central pancreatectomy in preserving the endocrine and exocrine functions of the pancreas is much debated. According to recent systematic review studies, the incidence of endocrine and exocrine insufficiency was significantly lower after the central pancreatectomy than that of pancreaticoduodenectomy or distal pancreatectomy [9, 18]. In a recent study by Lee et al. [24], central pancreatectomy had similar long-term endocrine function with distal pancreatectomy, and worse long-term exocrine function than distal pancreatectomy. In the current study, we evaluated the endocrine function by the state of diabetes mellitus, and we found that the new-onset or aggravated diabetes mellitus were nearly the same in the two groups. The outcome of endocrine function in this study (0–14% incidence) was consistent with the systematic review by Wu et al. [18] while

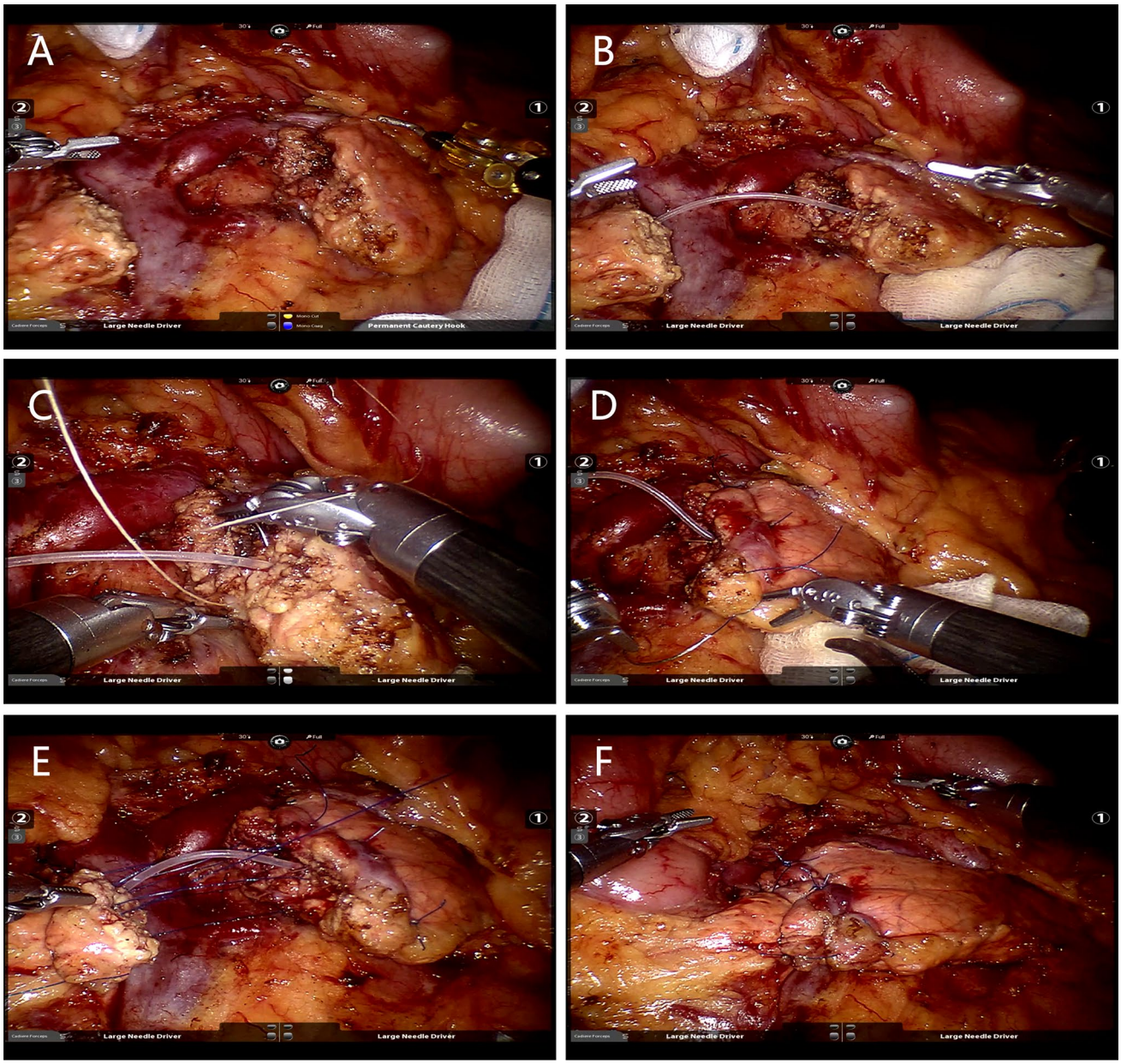

Fig. 1 **a** Resection of the central pancreas. **b**: Insertion of the pancreatic duct stent. **c**: Fixing the stent with main pancreatic duct. **d**: Reinforcement of the pancreatic stump. **e**: End-to-end anastomosis of two pancreatic stumps. **f**: Fig. 6_Completion of the end-to-end pancreatic reconstruction

better than that of distal pancreatectomy (3–40%) or pancreaticoduodenectomy (9–24%) in. In this study, 1.9% and 4.8% of patients developed chronic steatorrhea in the Rong's and PJ group, respectively ($p = 1.000$). This incidence was lower than previously reported exocrine insufficiency after open, distal pancreatectomy or pancreaticoduodenectomy. The postoperative chronic steatorrhea reflected a deficiency of pancreatic exocrine function [25]. Xiao et al. [9] reported that the open central pancreatectomy had a incidence of postoperative exocrine insufficiency of 6% (57/1114) after open central pancreatectomy, and minimally invasive central pancreatectomy of 9% (10/191), respectively ($p > 0.05$). Lee et al. [24] evaluate the exocrine function with tool elastase level, and suggested that patients underwent central pancreatectomy suffered mild exocrine pancreatic insufficiency while the patients underwent distal pancreatectomy had satisfied exocrine function.

The limitation of this study was the retrospective nature and small cohort of the study, and the follow-up period of the PJ group was significantly longer than that of the Rong's

group, some bias might occur in the data collection and analysis. The study was also a before and after study, and most of the PJ group were performed first and the Rong's group next, thus introducing the potential bias of the impact of the learning curve on outcomes. In addition, the surgery indications of the pancreatic cystic neoplasms were different from that of the European and American guidelines (Fig. 1).

Conclusion

Robotic Rong's central pancreatectomy with end-to-end anastomosis was safe and feasible. Compared with conventional robotic central pancreatectomy with pancreaticojejunostomy, it was less technology demanding and has superior perioperative outcomes and comparable long-term exocrine and endocrine functions. To further validate the efficacy of this novel procedure, a prospective study with a larger cohort are needed.

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Data availability The data that support the findings of this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Conflict of interests All authors declare that they have no conflict of interest or financial ties to disclose.

Human and/or animals rights The study was conducted in accordance with the ethical principles of the Helsinki Declaration for research on humans. The study was approved by the Ethical Committee of the PLA Central Hospital.

Informed consent Written informed consent was obtained from the all individual participants included in the study.

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