*Original Article*

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# Total laparoscopic versus robot-assisted laparoscopic pancreaticoduodenectomy

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**Summary** **In this study, the clinical effectiveness of the robot-assisted laparoscopic pancreaticoduodenectomy (RPD) and Total laparoscopic pancreaticoduodenectomy LPD were retrospectively reviewed. From December 2013 to September 2017, 20 patients underwent robot-assisted laparoscopic pancreaticoduodenectomy and 80 patients underwent Total laparoscopic pancreaticoduodenectomy. The clinical data of the RPDs and the first 20 LPDs were reviewed retrospectively. There is no difference in operative time, estimated blood loss, length of stay, and rates of complications and mortality between the LPD and RPD group. The next 10 cases in the RPD group had shorter operative times ($p = 0.03$) than the first 10 cases. The estimated blood loss and length of stay were also lower in the next 10 cases; however, these results did not reach statistical significance. Our results show that LPD and RPD are technically safe and feasible. Comparable results were demonstrated between the two groups, while the robotic system seemed to shorten the learning curve of minimally invasive pancreaticoduodenectomy (PD).**

***Keywords:*** Laparoscopic, robotic, pancreaticoduodenectomy, learning curve

## 1. Introduction

Laparoscopic pancreaticoduodenectomy (LPD) was first described by Gagner and Pomp in 1994 (*1*), and the first robotic-assisted LPD (RPD) was performed by Giulianotti *et al*. in 2001 (*2*). Minimally invasive pancreaticoduodenectomy (MPD) has gradually gained momentum following 30 years of development of laparoscopic surgical skills, internal closure devices, and energy systems. LPD is a well-established procedure with acceptable morbidity and mortality rates in some specialized high-volume centers (*3-8*). However, there are intrinsic disadvantages associated with traditional laparoscopy systems, including two-dimensional imaging, poor surgeon ergonomics, and a restricted range of movement up to four degrees of freedom inside the abdominal cavity (*9*). Application of a robotic surgical system is believed to provide surgeons with superior magnified high-resolution three-dimensional visualization, enhanced dexterity, greater precision, and greater ergonomic comfort. It enables surgeons to control the surgical instruments with accuracy, flexibility, and a wide range of motion. This is beneficial in procedures that require complicated resection and reconstruction such as prostatectomy, coronary surgery, and pancreaticoduodenectomy (PD). RPD has been proven feasible and safe with the advantage of minimal invasiveness compared with open procedures (*10-15*). However, robotic systems also have some disadvantages compared with laparoscopic systems, such as their high cost, lack of force feedback, and device-related complications. To the best of our knowledge, no directly comparative data between these two procedures have been reported to date. We herein present a case series with the aim of elucidating the short-term clinical effectiveness between LPD and LRPD by direct comparison.

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## 2. Materials and Methods

### 2.1. *Clinical data*

From December 2013 to September 2017, a total of 100 patients with periampullary tumors underwent MPD at Zhejiang Provincial People's Hospital, Hangzhou, China. The indication for MPD was the requirement for PD in the absence of locally advanced malignancy. All patients' general medical conditions were adequate for general anesthesia with pneumoperitoneum. The decision regarding whether to perform LPD or RPD was based on the patient's choice of procedure and the ability to pay for the extra cost associated with robotic surgery. All surgeries were performed by surgeons with experience in open PD and minimally invasive surgery. The clinical data of the first 20 LPDs and RPDs were analyzed to evaluate the LPD and RPD outcomes during the same period of the learning curve. This study was performed with approval of the Zhejiang Provincial People's Hospital review board committee.

The patients' demographic and clinical data were reviewed, including age, sex, body mass index, American Society of Anesthesiologists (ASA) grade (*16*), operative time, estimated blood loss (EBL), need for blood transfusions, tumor type, margin status, 90-day or in-hospital mortality, length of postoperative hospital stay (LOS), and readmission rate. Postoperative complications were graded using the Clavien–Dindo (CD) classification (*17*). Pancreatic fistula (*18*), bile leakage (*19*), postoperative hemorrhage (20), and delayed gastric emptying (*21*) were defined according to the established international consensus.

### 2.2. *Operative technique*

LPD or RPD was performed with the patient in the supine position and secured firmly to the operation table. After establishment of pneumoperitoneum by a closed Veress needle technique, ports were placed as shown (Figure 1).

The operation was started by laparoscopic examination of the entire abdomen. If no contraindications to resection were present, the transverse colon and hepatic flexure were completely mobilized from the head of the pancreas and duodenum. A wide Kocher's maneuver was then performed until the Treitz ligament had been completely mobilized and the right side of the superior mesenteric artery (SMA) had been exposed if possible (Figure 2). Dissection of the hepatoduodenal ligament was started by cystic artery transection and cholecystectomy. The common hepatic duct was divided and temporarily closed by a clip to avoid spillage of bile throughout the procedure if needed. Mobilization of the common bile duct to the superior border of the pancreas was performed with care to prevent injury to the aberrant right hepatic artery arising from the SMA. The underlying portal vein (PV) was identified at the same time. The distal stomach was transected with an endoscopic stapler. The superior border of the pancreas was visualized and the hepatic artery was identified and followed by transection of the gastroduodenal artery. The superior mesentery vein (SMV) was then dissected at the inferior border of the pancreas, and a retropancreatic tunnel was created if needed. The pancreas was then transected and the pancreatic duct found. The jejunum was pulled to the right upper quadrant under the mesenteric vessels and transected 10 to 15 cm distal to the ligament of Treitz with an endoscopic linear stapler. Dissection of the uncinate process of the pancreas from the right side of SMV and SMA was performed with traction of the uncinate process from the opposite side of the vessels (Figure 3). A Harmonic scalpel and Ligasure were applied in the transection. After this step, the resection part was finished (Figure 4).

Reconstruction was carried out *via* a laparoscopic or robotic system according to the patient's choice. A double-layer duct-to-mucosa pancreaticojejunostomy was carried out using 3-0 Prolene (Ethicon, Somerville, NJ) running sutures for the outside layer and 5-0 Prolene (Ethicon) interrupted sutures for the inner layer (Figure 5). A pancreatic stent was used in all cases. The hepatojejunostomy was performed using a 4-0 polydioxanone (PDS II; Ethicon) in a running fashion. Gastrojejunostomy was performed intracorporeally using 3-0 Stratafix (Ethicon) in both LPD and RPD. The specimen was removed *via* an enlarged periumbilical incision (3-4 cm).

### 2.3. *Statistical analysis*

Results are presented as mean ± standard deviation. Patients who underwent LPD were compared with those who underwent RPD using the chi-square test and Fisher's exact test for categorical variables and the Mann–Whitney *U* test for continuous variables. Differences with p values of $< 0.05$ were considered statistically significant. All analyses were performed using SPSS 13.0 statistical software (SPSS Inc., Chicago, IL).

## 3. Results

Twenty patients underwent a robotic procedure and eighty underwent a laparoscopic technique. Four LPDs were converted to open surgery: one because of intraoperative bleeding and three because the tumors invaded the portal vein or SMV, preventing R0 resection using a minimally invasive procedure. Tumor resection was performed *via* a laparoscopic system in all cases in our group. All four cases that converted to open procedures were at the resection stage with the laparoscopic system, so they were excluded from the analysis.

The demographic and preoperative clinical characteristics of the first 20 RPDs and LPDs are listed in Table 1. There was no significant difference in sex, age, body mass index, or ASA grade between the two

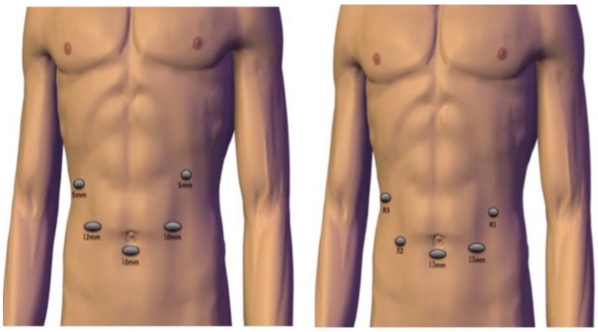

**Figure 1. Trocar positions. Left picture shows the port positions in LPD procedures and the right one shows the port positions in RPD procedures.**

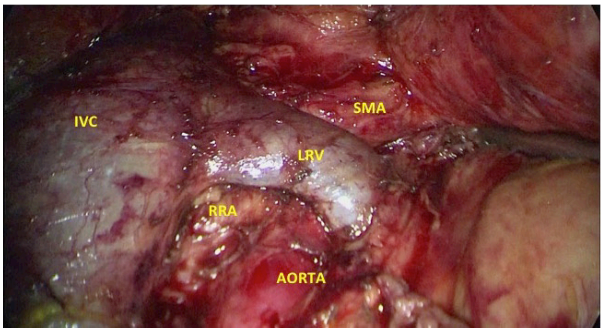


**Figure 2. Right retrospective SMA first approach.** SMA, superior mesentery artery; IVC, inferior vein cava; LRV, left renal vein; RRA, right renal artery.

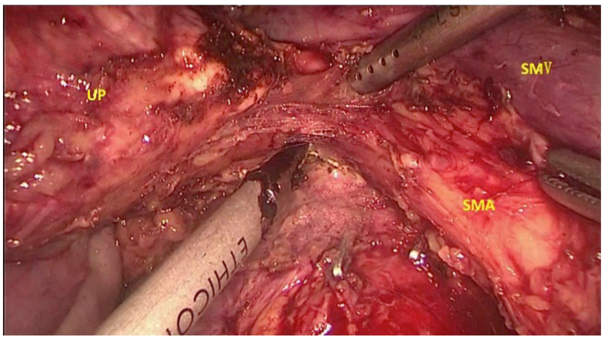


**Figure 3. Dissection of the uncinate process of the pancreas from the right side of SMV and SMA.** UP, uncinate process of the pancreas; SMA, superior mesentery artery; SMV, superior mesentery vein.

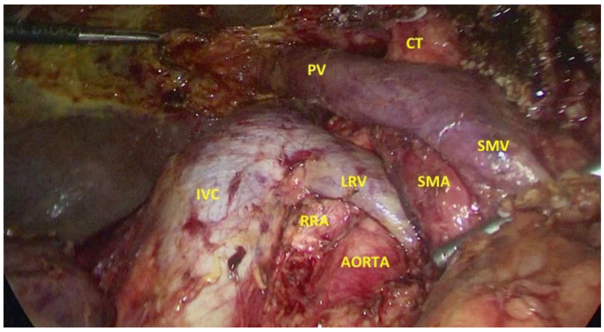


**Figure 4. Complete resection.** CT, celiac truck; PV, portal vein; SMA, superior mesentery artery; SMV, superior mesentery vein; IVC, inferior vein cava; LRV, left renal vein; RRA, right renal artery.

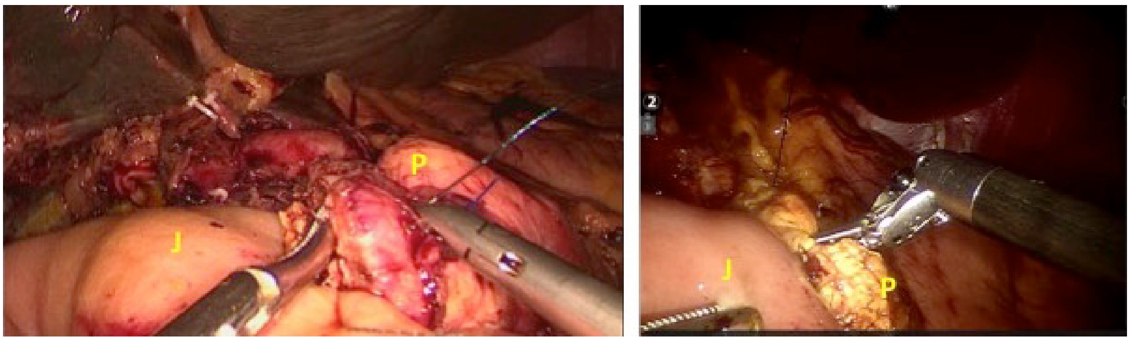


**Figure 5. Pancreaticojejunostomy, left figure shows laparoscopic pancreaticojejunostomy and right figure shows robotic pancreaticojejunostomy.** P, pancreases; J, jejunum.

groups.

The perioperative results are shown in Table 2. The operation time was 407.0 ± 91.8 and 373.8 ± 70.2 minutes in RPD group and LPD group. The estimated blood loss was 220.5 ± 165.5 and 240.0 ± 239.5 ml in RPD group and LPD group, and the LOS was 14.6 ± 6.1 and 18.1 ± 11.6 days in RPD group and LPD group. However, the differences between the two groups did not reach statistical significance. The rates of overall and major complications (CD grade ≥ II) were similar between the two groups. One patient in the RPD group died of postoperative intra-abdominal active bleeding from the GDA. This patient had embolization of the common hepatic artery and rebleeding after embolization and ultimately died of multiple organ dysfunction. The occurrence of postoperative pancreatic fistula, delayed gastric emptying, bile leakage, and bleeding were similar in the two groups. There was no significant difference in the reoperation and readmission rates between the two groups.

Because of the limited number of procedures performed, it was impossible to analyze the learning curve of the two procedures. We simply separated each group into two subgroups: the first 10 cases and the last 10 cases. The clinical data between these two subgroups were analyzed. As shown in Table 3, there is no difference between the last 10 cases and the first 10 cases in the LPD group. In the RPD group, the last 10 cases had significantly shorter operative times ($p$ = 0.03) than the first 10 cases. The EBL and LOS were also lower in the last 10 cases; however, these results did not reach statistical significance. More major complications (CD grade ≥ II) occurred in the first than last 10 cases in both groups (LPD, 4 *vs*. 2; RPD, 3 *vs*. 2, respectively). The occurrence of postoperative pancreatic fistula was the same between the first and last 10 cases in both groups (LPD, 3 *vs*. 2; RPD, 2 *vs*. 1, respectively).

The pathologic results are shown in Table 4. All patients had negative resections, and no difference in the final diagnosis was noted between the two groups.

**Table 1. Patients' demographic and preoperative clinical characteristics**

| Items | LPD (20) | RPD (20) | *P* |
|---|---|---|---|
| Gender | M:F 11:9 | M:F 12:8 | NS |
| Age (median) | 42-76(64) | 50-78(68) | NS |
| BMI (kg/m$^2$) | 24.0 ± 3.5 | 24.8 ± 2.5 | NS |
| ASA | | | |
| II | 16 | 14 | NS |
| III | 4 | 6 | |
| Jaundice (TB ≥ 2 mg) | 5 | 7 | NS |
| DM | 4 | 3 | NS |
| Pancreatic duct (> 3 mm) | 13 | 9 | NS |

LPD: laparoscopic pancreaticoduodenectomy, RPD: robot-assisted laparoscopic pancreaticoduodenectomy, BMI: body mass index in kg/m2, ASA: American Society of Anesthesiologists grade, TB: total bilirubin, DM: diabetes mellitus, NS: no significant difference.

**Table 2. Perioperative clinical findings and complications**

| Items | LPD (20) | RPD (20) | *P* |
|---|---|---|---|
| OT (mins) | 373.8 ± 70.2 | 407.0 ± 91.8 | NS |
| EBL (ml) | 240 ± 239.5 | 220.5 ± 165.5 | NS |
| Mortality | 0 | 1 | NS |
| Morbidity (CD ≥ II) | 9 | 8 | NS |
| Pancreatic fistula | | | NS |
| A | 2 | 2 | |
| B | 1 | 0 | |
| C | 2 | 1 | |
| Bile leakage | 2 | 1 | NS |
| DGE | 1 | 2 | NS |
| Hemorrhage | 3 | 2 | NS |
| Reoperation | 3 | 3 | NS |
| LOS (days) | 18.1 ± 11.6 | 14.6 ± 6.1 | NS |
| Readmission | 1 | 0 | NS |

LPD: laparoscopic pancreaticoduodenectomy, RPD: robot-assisted laparoscopic pancreaticoduodenectomy, OT: operation time (from cutting of the skin to completion of suturing), EBL: estimated blood loss, LOS: length of postoperative hospital stay, CD: Clavien-Dindo classification, DGE [26]: delayed gastric emptying.

## 4. Discussion

After 30 years of development, MPD has been proven safe and has shown some benefits over traditional open procedures, including less pain, less blood loss, better cosmetic outcomes, and faster recovery. However, the complexity of the anatomy during dissection and the need for reconstruction with two challenging anastomoses (pancreatic-enteric and hepato-enteric anastomosis) have made MPD more technically demanding and limited this procedure to a few experienced hands in high-volume centers. Recently reported large series (> 100 cases) of LPD (*4,6*) have clearly shown that this is a well-established approach. However, LPD has inherent disadvantages such as two-dimensional visualization and a limited degree of freedom due to the straight laparoscopic instruments. These limitations have made some parts of the procedure, such as pancreatic-enteric reconstruction, very technically demanding. Robotic systems have provided surgeons with superior three-dimensional visualization and instrumentation that mimics the surgeon's hand; these instruments have an articulating wrist, are able to achieve seven degrees of freedom, and provide tremor filtration and stable retraction (*22*). The emergence of robotic systems has captured the attention of many minimally invasive surgeons because it is often believed to overcome the natural limitations of conventional laparoscopy. However, the efficiency of robotic surgery continues to be debated because of its extra cost, lack of force feedback, and device-related complications. Several retrospective reports have compared the safety and feasibility between RPD and open PD (*11,14,23*) and between LPD and open PD

**Table 4. Pathological results of the two procedures**

| Items | LPD (20) | RPD (20) | *P* |
|---|---|---|---|
| PDAC | 8 | 7 | NS |
| Cholangiocarcinoma | 6 | 4 | NS |
| Ampulla adenocarcinoma | 4 | 5 | NS |
| NET | 0 | 2 | NS |
| IPMN | 1 | 0 | NS |
| Other | 1 | 2 | NS |

LPD: laparoscopic pancreaticoduodenectomy, RPD: robot-assisted laparoscopic pancreaticoduodenectomy, PDAC: pancreatic duct adenocarcinoma, NET: neuroendocrine tumor, IPMN: intraductal papillary mucinous neoplasm.

**Table 3. Comparison of the first and last 10 cases**

| Items | LPD | | | RPD | | |
|---|---|---|---|---|---|---|
| | LPD (1-10) | LPD (11-20) | *P* | RPD (1-10) | RPD (11-20) | *P* |
| OT (mins) | 383.0 ± 95.8 | 364.5 ± 32.1 | NS | 449 ± 105.9 | 365 ± 51.5 | 0.03 |
| EBL (mL) | 257.0 ± 288.0 | 223.0 ± 193.7 | NS | 290 ± 243.6 | 171 ± 108.4 | NS |
| LOS (days) | 19.4 ± 14.7 | 16.7 ± 8.3 | NS | 16.5 ± 8.0 | 12.7 ± 3.0 | NS |

LPD: laparoscopic pancreaticoduodenectomy, RPD: robot-assisted laparoscopic pancreaticoduodenectomy, OT: operation time, EBL, estimated blood loss, LOS: length of postoperative hospital stay.

(*6,10,24,25*). The results showed that LPD and RPD had some benefits over open PD. However, whether robot-assisted procedures have advantages over laparoscopic procedures for PD remains unclear.

Our RPD procedures were performed *via* a hybrid laparoscopic-robotic approach (*13,26,27*). We started with laparoscopic resection followed by reconstruction using a robotic system. We chose this approach to maximize the advantages and bypass the disadvantages of both techniques. The advantages of traditional laparoscopic resection were that it had some force feedback, the ability to change the patient's position during the operation, and the fact that the laparoscopic technique was very well developed. However, the robotic system was proven to be better for procedures performed in small, confined areas and that require superior visualization and a precise technique, such as prostatectomy and coronary artery bypass surgery. For these reasons, we believe that robotic systems are beneficial for challenging reconstructions, including pancreatic-enteric and hepato-enteric anastomosis. However, the current robotic systems also have several disadvantages, including the inability to change the position of the patient after docking, the high cost not covered by health insurance, and incompatibility with current systems. According to these differences between the two systems, we believe that traditional laparoscopy is better than robotic surgery for resection, while robotic surgery is better for reconstruction.

In the present study, we found no significant difference in the operative time or EBL between the two groups. The operative time in the RPD group (407.0 ± 91.8 min) was longer than that in the LPD group (373.8 ± 70.2 min). Our operative time was the "skin-to-skin" interval, which included the docking time of the robotic system, which was usually about 40 minutes in the first 10 cases and 20 minutes in the next 10 cases. We also found a greater reduction in the operative time in the RPD group ($p = 0.03$). The operative time was longer in the RPD than LPD group in the first 10 cases (449.0 ± 105.9 *vs*. 383.0 ± 95.8 min, respectively) and almost the same in both groups in the next 10 cases (364.5 ± 32.1 *vs*. 365.0 ± 51.5 min, respectively). We believe that this reduction was mainly the result of familiarity with the robotic system. Less intraoperative bleeding is widely accepted as one of the major advantages of the minimally invasive approach. The EBL in the present study was similar in the LPD and RPD groups (240.0 ± 239.5 *vs*. 220.5 ± 165.5 ml, respectively). This indicates that both minimally invasive approaches effectively reduced bleeding by allowing for precise manipulation and providing magnification.

PD is a complex procedure with a high morbidity rate even in high-volume centers (*28*). Our results showed that the occurrence of complications was similar in the two groups according to the CD classification system, and the incidence of postoperative complications (CD grade ≥ II) in the RPD (40%) and LPD (45%) groups was in accordance with the previously published open PD data (*28*). This indicates that both of these minimally invasive procedures are as safe as the open approach. The pancreatic fistula continues to be the "Achilles' heel" of PD, and most of the serious complications of PD are associated with POPF. The incidence of pancreatic fistula was 10% to 20% after PD according to the International Study Group of Pancreatic Surgery classification (*20,28,29*). Some experienced surgeons have tried to improve the anastomosis techniques for PD (*30*). However, the development of pancreatic fistulas continues to be problematic. In the present study, the incidence of pancreatic fistulas was not significantly different between the two groups (25% *vs*. 15%) and included a severe (grade C) pancreatic fistula. These findings are similar to those reported in a larger-volume open series (*28*). The incidence of severe pancreatic fistula was 10% in the LPD group and 5% in the RPD group of the present study; this might have been due to the fact that our series was performed when the surgeon was in the learning stage of both procedures, and the anastomotic technique and peripancreatic drainage were therefore imperfect.

The patients in the LPD group had a longer LOS (18.1 ± 11.6 days) than those in the RPD group (14.6 ± 6.1 days), but the difference was not statistically significant. This indicates expedited postoperative recovery in the RPD group. In contrast, a previous review showed that patients who underwent LPD had a shorter LOS than those who underwent RPD (11.09 ± 7.00 *vs*. 13.84 ± 8.00 days, respectively) (*31*). However, they compared data from different institutions located on different continents with different health insurance systems. We believe that the patients who underwent RPD in the present study had an expedited postoperative recovery. The lack of statistical significance might have been due to the insufficient statistical power.

The number of cases in our series was small, so it is difficult to quantify the learning curve. We compared the clinical data of the first and next 10 cases in each group. Several interesting findings emerged from this comparison. Limited improvement in the measured parameters was achieved in the LPD group. However, improvements were detected in the RPD group. A significant decrease in the operative time in the next 10 cases was found in the RPD group ($p = 0.03$). The EBL and LOS were decreased in next 10 cases, although the difference did not reach statistical significance because of the small number of cases. In our opinion, the main reason is the difference in the surgeon's skill level between the two systems. The surgeon who performed the operations was a well-trained laparoscopic surgeon. Therefore, the surgeon's laparoscopic technique was fully developed when LPD was started. Because the robotic system was new and high-cost, there was limited opportunity to train the surgeon in simple procedures such as cholecystectomy before we start RPD. We believe that this was the main reason for this difference. From another point of view, the robotic system has great potential for improved performance in the future. Furthermore, our data demonstrated that RPD might be associated with a shorter learning curve than LPD.

There was no difference in the final pathological results between the two groups. All patients had a negative resection margin, and the lymph nodes harvested were the same in all patients with pancreatic cancer (data not shown). Because of the limited number of cases, the survival benefit could not be determined.

In conclusion, LPD and RPD had comparable short-term results. Both approaches were technically feasible with acceptable short-term outcomes in experienced hands. There was a steep learning curve for both LPD and RPD; however, RPD seems to have a shorter learning curve for this complex procedure. A further large-volume study should be performed to compare the long-term outcomes between LPD and RPD.

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