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A novel laparoscopic pancreaticoduodenal training model: optimization of the learning curve and simplification of postoperative complications

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Purpose: Laparoscopic pancreaticoduodenectomy requires a long learning curve. A preoperative training system was established to optimize the surgeons' learning curve and reduce the incidence rate of complications at the beginning of the curve.
Methods: The laparoscopic pancreaticojejunostomy model, and choledochojejunostomy and gastrojejunostomy training systems were developed, and corresponding evaluation systems were also defined. Surgeons B and C performed laparoscopic pancreaticoduodenectomy after completing training session. Surgical outcomes, postoperative complications and their learning curves were analyzed.
Results: Patients operated by surgeons B and C experienced shorter operative durations following training session than those in nontrained group (called A) ($P < 0.001$). B and C began entering the inflection point at the 26th and 20th case in learning curve, respectively. The incidence of postoperative pancreatic fistula in group B was 3.3%, significantly lower than 13.1% in group A ($P = 0.047$). Patients in group B showed significantly lower incidence of biliary-enteric anastomosis leakage (0% vs. 8.2%, $P = 0.029$) and Clavien–Dindo classification greater than or equal to 3 (3.3% vs. 14.8%, $P = 0.027$) compared with those in group A. The incidence of surgical site infection in groups B (3.3%, $P = 0.004$) and C (4.9%, $P = 0.012$) was significantly lower than that in group A (19.7%). Moreover, the length of postoperative hospital stay was significantly shorter in groups B (12.5 ± 5.9 days, $P = 0.002$) and C (13.7 ± 6.5 days, $P = 0.002$) compared with group A (16.7 ± 8.5 days).
Conclusions: The laparoscopic pancreaticojejunostomy training model and evaluation system can shorten the operative duration, lower the risk of postoperative complications, and shorten the length of hospital stay.

Keywords: Education, laparoscopy, learning curve, pancreaticoduodenectomy, postoperative complication

Introduction

As laparoscopic pancreaticoduodenectomy (LPD) techniques advance, LPD and robot-assisted pancreaticoduodenectomy (RPD)[1–3] are being widely applied in clinical settings. Although LPD is known to the medical community for its thoroughness, its safety continues to be questioned. A large, multicenter clinical study in which we participated has confirmed that LPD is a feasible and safe procedure when performed by experienced surgeons, resulting in shorter length of hospital stay and short-term morbidity and mortality similar to open pancreaticoduodenectomy (OPD)[4].

HIGHLIGHTS

- Laparoscopic pancreaticoduodenectomy and robot-assisted pancreaticoduodenectomy are being widely applied in clinical settings.
- Multiple postoperative complications caused by surgeons inexperienced in anastomosis techniques.
- LPD preoperative training system for pancreaticojejunostomy, choledochojejunostomy, and gastrojejunostomy.

On the other hand, LPD requires a longer learning curve than OPD, having an inflection point at 80–100 cases[5–7]. As a value of reference in the cumulative sum of successes, we considered our own complication rate. The cumulative-sum curve of pancreatic fistula had an inflection point at 44 cases, biliary-enteric anastomosis leakage had an inflection point at 46 cases, and the severe-complication curve had an inflection point at 40 cases, consistent with previous studies on LPD reported by van Workum *et al.*[8–10]. Hence, relatively severe complications were reduced after ~50 cases or more. To address the issues of the long learning curve for LPD and multiple postoperative complications caused by surgeons inexperienced in anastomosis techniques, we established an LPD preoperative training system for pancreaticojejunostomy, choledochojejunostomy, and gastrojejunostomy, hoping to provide certain evidence for lowering the complication rate in the first 50 consecutive cases of LPD.

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Methods

Training model development and technique evaluation

As severe postoperative complications after LPD are primarily associated with inadequate skills in digestive tract reconstruction, separate training and evaluation systems were developed and established for LPD, choledochojejunostomy, and gastrojejunostomy, respectively.

LPD training and evaluation system

Preparation of pancreas model

The bovine liver was dissected along the yellow line, leading to many cross sections (Fig. 1A). The texture of bovine liver resembled that of human pancreas, and the bile duct diameter of 3–4 mm after the dissection segment of bovine liver was similar to that of the pancreatic duct stump in human LPD procedure, which was appropriate for duct-to-mucosa anastomosis training (Fig. 1B).

Surgical simulation using LPD model

Reconstruction of the pancreaticojejunostomy system (Fig. 1C): Duct-to-mucosa reconstruction was performed (operative time was recorded). 3-0 Prolene (WB558; Ethicon) was used for full-thickness suturing of the bovine liver and outer mucosa of the jejunum. Anastomosis was performed using a commercially available pancreatic duct stent made of silicone gel (Ethicon). The proximal part of the silicone gel stent was placed into the pancreatic duct and jejunal mucosal duct model, while the distal part was introduced through the distal jejunum for subsequent evaluation of the anastomosis. The bovine liver duct and jejunal mucosa models were sutured using interrupted sutures of 5-0 PDS II (W9073, Ethicon). 3-0 Prolene (WB558; Ethicon) was used to the continuous suturing technique of the bovine liver model anterior mucosa and outer mucosa of the jejunum. LPD model (Fig. 1D) and LPD were anastomosed in the same pattern.

Evaluation of LPD technique

Methylene blue was injected into the silicone tube and normal pancreatic ductal pressure of 1.26 kPa (12.6 mm H_2O) was simulated. The pancreatic-intestinal anastomosis model area was observed for leakage, and if there was no leakage, the anastomosis was considered successful (Fig. 1E). The cumulative success should be greater than 50 times. The time taken to create the pancreatic-intestinal anastomosis was recorded and needed to be less than 30 min.

Laparoscopic choledochojejunostomy training and evaluation system

The cases in which laparoscopic choledochojejunostomy was performed during biliary cyst procedures were selected, and laparoscopic biliary exploration for T-duct-to-incision suturing during common bile duct stone procedures as training models for LPD choledochojejunostomy. PDS II (5-0) was chosen for hepaticojejunostomy, using continuous sutures on the anterior and posterior walls of the bile ducts (Fig. 1F). Subsequently, T-duct incision closure was performed using Covidien 4-0 V-Loc (VLOCL0803; Covidien/Medtronic) sutures (Fig. 1G). The technique of choledochojejunostomy evaluation was required for laparoscopic bile duct-jejunum anastomosis and laparoscopic T-tube incision suture greater than 30 cases, and postoperative complication rate of bile leak was less than 5%.

Laparoscopic gastrojejunostomy training and evaluation system

The cases of palliative short-circuit surgery and subtotal gastrectomy surgery were chosen as training models for laparoscopic gastrojejunostomy. During training session, a Covidien Endo GIA stapler (EGIAUSYND, EGIA60AVM, EGIA60AMT; Covidien) was adopted to perform the gastrojejunostomy anterior to the mesocolon (Fig. 1H). The gastrojejunostomy evaluation technique required laparoscopic gastrointestinal anastomosis practice for more than 20 cases, and postoperative complication rates for anastomotic leak and haemorrhage were less than 5%.

Training participants

Surgeons B and C completed the training in 11 and 14 months, respectively, and neither had performed an LPD as a surgical practitioner before the start of the study. However, both surgeons B and C had completed open Whipple procedures as operating surgeons ($n=56$ for surgeon B, n = 44 for surgeon C) and LPD procedures as first assistants ($n=44$ for surgeon B, $n=41$ for surgeon C).

Study design

As described in our previous clinical study[5] on LPD, the first 61 surgeries by surgeon A (group A) without LPD training system were in the ascending learning phase of the LPD learning curve. Therefore, 61 cases of LPD performed separately by either of surgeons B and C (groups B and C) were regarded as controls in this study. All patients had undergone necessary clinical and laboratory examinations to assess the primary tumour invasion, vascular invasion, and distant metastasis to ensure that the surgical cases included for surgeons B and C were similar to the 61 cases for surgeon A and that the level of difficulty of LPD was relatively low. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The Institutional Review Board of our hospital has approved the study protocol. This study had been approved by our hospital.

Inclusion criteria: tumours located at the lower part of the common bile duct and ampulla; benign and malignant pancreatic tumours located at the head of the pancreas; the patient had never undergone gastrointestinal surgery; and no tumour invasion of the coeliac trunk, common hepatic artery, or superior mesenteric artery. Exclusion criteria: the patient was unable to tolerate general anaesthesia and arterial invasion as well as distant metastases. Accordingly, each patient had signed an informed consent form concerning the operation and the use of data on their health status before and after the operation.

As with the 61 LPD cases in the previous cohort of group A, before the operation, percutaneous transhepatic cholangial drainage was performed in patients with serum bilirubin exceeding 200 μmol/l. Frozen sections were prepared to examine the surgical margins of the common bile duct/pancreas, with pathologic examination to meet the R0 standard.

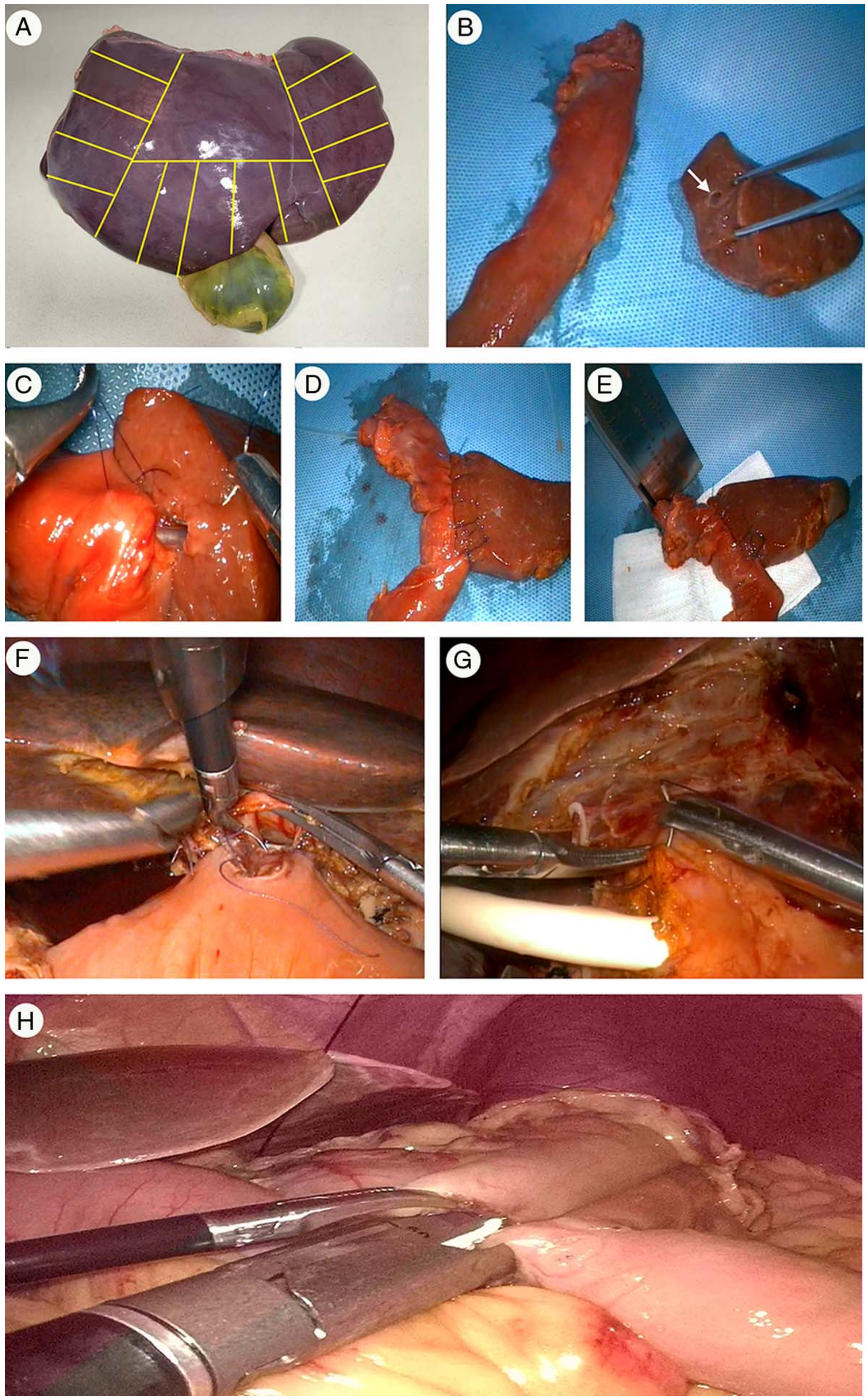

Figure 1. Preparation of the pancreas model. (A) Preparation of the pancreas model. (B) Surgical simulation using laparoscopic pancreaticojejunostomy model. Laparoscopic pancreaticojejunostomy training and evaluation system. (C) Laparoscopic duct-to-mucosa reconstruction. (D) Laparoscopic pancreaticojejunostomy model. (E) Technique of laparoscopic pancreaticojejunostomy evaluation. Laparoscopic choledochojejunostomy training. (F) Continuous sutures in the bile ducts and jejunum. (G) Interrupted sutures T-duct incision closure. (H) Laparoscopic gastrojejunostomy training. Stapler used to perform laparoscopic gastrojejunostomy.

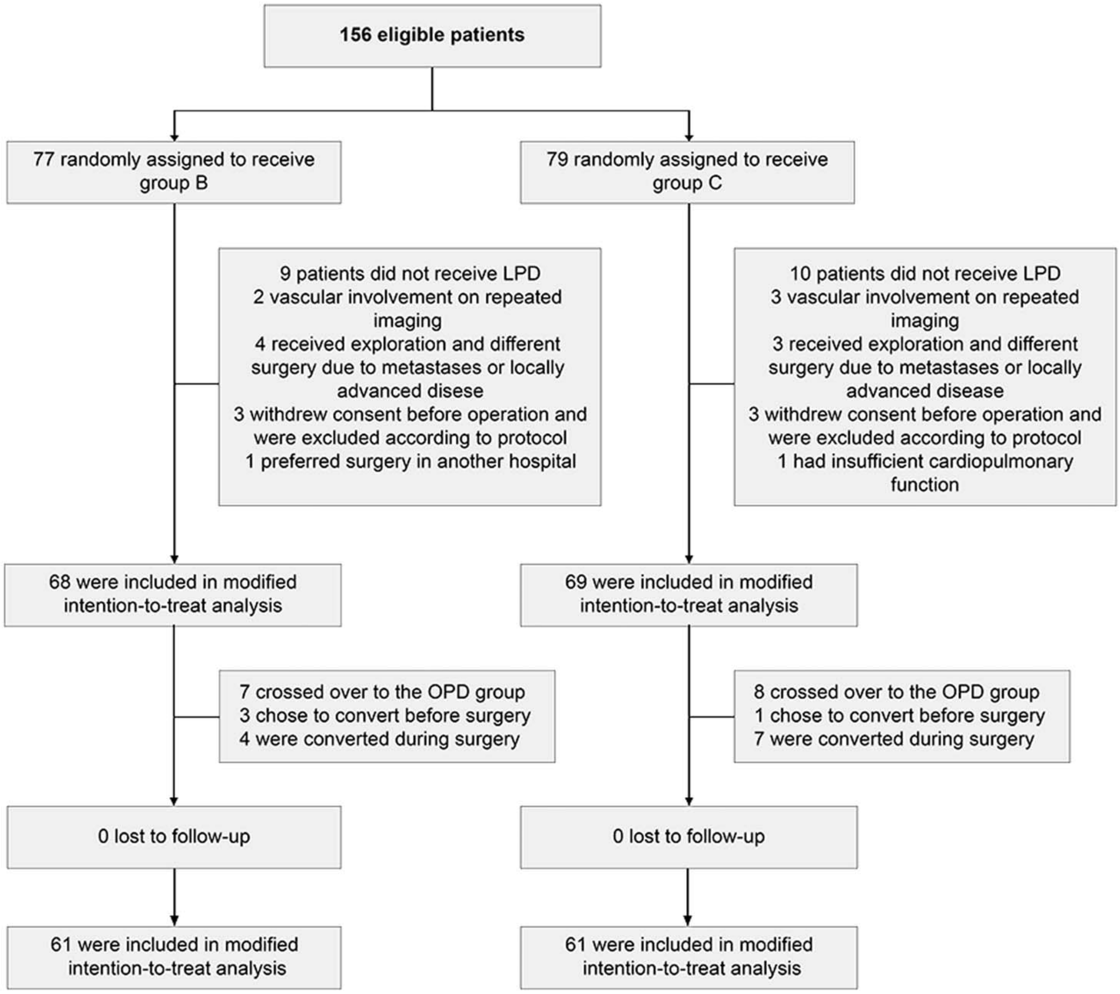

Figure 2. Trial profile. LPD, laparoscopic pancreaticoduodenectomy; OPD, open pancreaticoduodenectomy.

Biostatistics and statistical analysis

The clinicopathological characteristics of patients and their postoperative outcomes, including operative duration, estimated blood loss, and histopathological characteristics and complications[11], including diagnosis and classification of pancreatic ductal adenocarcinoma, were collected. All continuous data were presented as median and mean ± standard deviation, and frequencies were presented when appropriate for the type of data. The means of the continuous variables were compared using the two-tailed student's *t*-test, and variables that

Table 1

Clinicopathological characteristics of patients ($n = 183$).

	Group (n)				
Variables	**A (1–61)**	**B (1–61)**	**C (1–61)**	**Total**	***P***
Age, mean (SD), year	61.3 (10.0)	62.2 (9.4)	62.6 (9.1)	62.0 (9.5)	0.752
Female, *N* (%)	23 (37.7)	20 (32.8)	25 (41.0)	68 (37.2)	0.641
BMI, mean (SD)	22.87 (3.1)	22.85 (4.2)	23.54 (5.4)	23.09 (4.3)	0.607
ASA physical status, *n* (%)					
1	29 (47.5)	28 (45.9)	25 (41.0)	82 (44.8)	
2	28 (45.9)	28 (45.9)	30 (49.2)	86 (47.0)	
≥ 3	4 (6.6)	5 (8.2)	6 (9.8)	15 (8.2)	0.937
Tumour size on imaging, mean (SD), mm	21.7 (9.1)	22.6 (11.3)	21.3 (9.3)	21.9 (9.9)	0.747
Preoperative biliary drainage, *n* (%)	19 (31.3)	23 (37.7)	24 (39.3)	66 (36.1)	0.608
PDAC patients, *n* (%)	13 (21.3)	17 (27.9)	11 (18.0)	41 (22.4)	0.415

$P < 0.05$ as statistically significant.
Data are expressed as mean (SD) and *n* (%).
ASA, American Society of Anesthesiologists; PDAC, pancreatic ductal adenocarcinoma.

Table 2

Surgical outcomes and histopathological characteristics.

	Group (*n*)				
	A (1–61)	**B (1–61)**	***P***	**C (1–61)**	***P***
Operative duration, mean (SD), min	476.9 (66.7)	380.7 (65.0)	**< 0.001**	400.4 (73.9)	**< 0.001**
Estimated blood loss, mean (SD), ml	350.3 (128.6)	332.5 (132.9)	0.456	338.2 (126.6)	0.604
Conversion (laparoscopy to open), *n* (%)	4 (6.6)	3 (4.9)	0.697	2 (3.3)	0.402
Pancreas duct size, mean (SD), mm	3.98 (1.4)	4.18 (1.6)	0.444	4.17 (1.3)	0.423
Pancreas texture (hard:soft), *n* (%)	16 (26.2)	18 (29.5)	0.840	14 (23.0)	0.834
LN harvest, mean (SD), *n*	10.5 (4.7)	12.1 (4.5)	0.057	11.1 (4.7)	0.492
Margin status (R0:R1), *n* (%)	57 (93.4)	58 (95.1)	> 0.999	57 (93.4)	> 0.999

Bold values are in statistically significant
$P < 0.05$ as statistically significant. Data are mean (SD), *n* (%).
LN, lymph node.

were not normally distributed were analyzed using nonparametric statistical tests. Categorical variables were presented as numbers and percentages and compared using Pearson's χ^2 test or Fisher's exact test (frequency ≤ 5) for contingency tables. The IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp) was used for statistical analyses. The learning curve for LPD was evaluated using the cumulative sum, which was calculated using the Intercooled Stata 13.0 statistical software package, and the GraphPad (9.1.2 GraphPad Software) software was used for plotting. For all analyses, a *P* value less than 0.05 was considered statistically significant.

Results

Baseline characteristics

Between 20 February 2020, and 12 November 2021, 156 patients eligible for all inclusion and exclusion criteria were randomly assigned into group B ($n = 77$) or group C ($n = 79$). 19 patients were excluded before surgery (9 in group B and 10 in group C) because of the following reasons: preoperatively detected vascular involvement on repeated imaging examination, patient withdrawal, exploration and different surgery due to metastases or locally advanced disease (gastrojejunostomy and biliojejunostomy), preferred surgery in another hospital, and cardiopulmonary function insufficiency (Fig. 2). Patients were included in groups B ($n = 61$) and C ($n = 61$) based on intention-to-treat analysis, having gone through the previous LPD training system (Table 1). The mean age of all patients was (62.0 ± 9.5) years. 37.2% of the patients were female. The average BMI was 23.09. The percentage of American Society of Anesthesiologists scores was 44.8% and 47.0% for grades 1 and 2 and 8.2% for grade 3, respectively. The mean size of the neoplasm was (21.9 ± 9.9) mm on preoperative imaging assessment. 66 (36.1%) patients underwent preoperative biliary drainage, of whom 41 were diagnosed with pancreatic ductal adenocarcinoma, accounting for 22.4% of the severe cases. There was no statistical difference in clinicopathological characteristics among the above three groups.

Surgical outcomes and cumulative-sum analysis of the learning curve

In terms of surgical outcomes (Table 2), there was no significant difference in pancreatic duct size and pancreas texture among groups A, B, and C. However, the mean operative duration was (380.7 ± 65.0) min in group B and (400.4 ± 73.9) min in group C following the LPD training, which was significantly faster than (476.9 ± 66.7) min in group A without training (both $P < 0.001$). Nevertheless, there were no statistically significant differences among the three groups regarding estimated blood loss, conversion (laparoscopy to open), lymph node dissection, and rate of R0 resection, respectively.

The inflection point of the operative duration in groups B and C was assessed using the cumulative sum. The coefficient of determination in group B, that is, R2 = 0.8198, started to enter

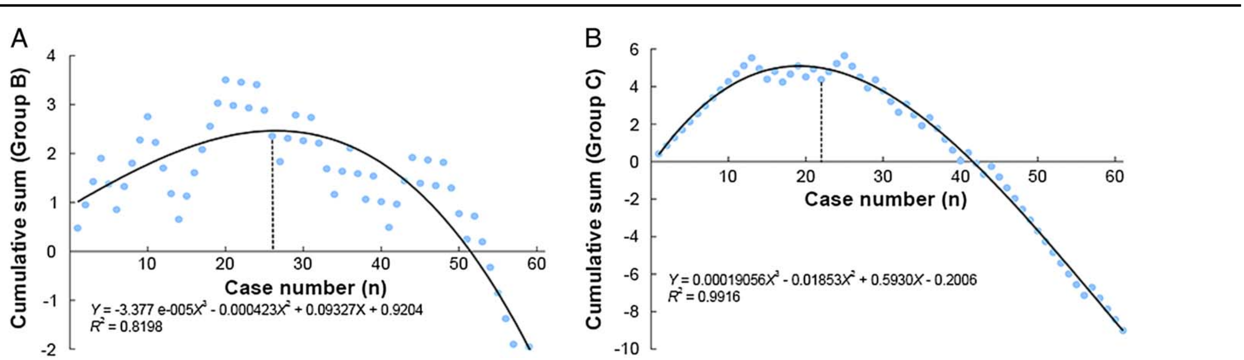

Figure 3. CUSUM analysis of operative duration and the inflection point. (A) CUSUM analysis of laparoscopic pancreaticoduodenectomy (LPD) operative duration of Group B, the inflection point at the 26th case (B) CUSUM analysis of LPD operative duration of Group C, the inflection point at the 20th case.

Table 3

Postoperative complications.

	Group (*n*)				
	A (1–61)	B (1–61)	*P*	C (1–61)	*P*
Pancreatic fistula					
Biochemical leak, *n* (%)	8 (13.1)	5 (8.2)	0.279	6 (9.8)	0.389
POPF (B and C), *n* (%)	8 (13.1)	2 (3.3)	**0.047**	3 (4.9)	0.102
Biliary-enteric anastomosis leakage, *n* (%)	5 (8.2)	0	**0.029**	1 (1.6)	0.104
Post-pancreatectomy haemorrhage, *n* (%)	6 (9.8)	3 (4.9)	0.246	2 (3.3)	0.136
Gastrointestinal haemorrhage, *n* (%)	4 (6.6)	7 (11.5)	0.265	8 (13.1)	0.106
Surgical site infection, *n* (%)	12 (19.7)	2 (3.3)	**0.004**	3 (4.9)	**0.012**
Clavien–Dindo Classification ≥III, *n* (%)	9 (14.8)	2 (3.3)	**0.027**	3 (4.9)	0.063
Surgical reintervention, *n* (%)	8 (13.1)	3 (4.9)	0.102	4 (6.6)	0.106
Complication-related mortality, *n* (%)	4 (4.9)	0	0.122	1 (1.6)	0.182
Postoperative LOS,mean (SD), days	16.7 (8.5)	12.5 (5.9)	**0.002**	13.7 (6.5)	**0.031**

Bold values are in statistically significant

$P<0.05$ as statistically significant.

Data are mean (SD) and *n* (%).

LOS, length of hospital stay; POPF, postoperative pancreatic fistulas.

the inflection point at the 26th case in the learning curve (Fig. 3A). The coefficient of determination in group C, that is, R2 = 0.9916, started to enter the inflection point at the 20th case in the learning curve (Fig. 3B).

Postoperative complications

The postoperative complications in group A with those in groups B and C were illustrated in Table 3. Concerning postoperative pancreatic fistula in groups B and C, there were two (3.3%) cases of pancreatic leak in group B, significantly less than eight (13.1%) cases in group A ($P=0.047$). There were three cases (4.9%) of pancreatic leak in group C, with no statistical significance ($P=0.102$). No biliary-enteric anastomosis leakage was observed in group B, significantly less than the five cases (8.2%) in group A ($P=0.029$), and one case (1.6%) in group C, which was not statistically significant compared with group A. The incidence of surgical site infection was significantly lower in group B was 3.3% ($n=2$, $P=0.004$), lower compared 4.9% ($n=3$, $P=0.012$) in group C, and 19.7% ($n=12$) in group A. The incidence of Clavien–Dindo Classification ≥III in group B was also significantly lower than that in group A ($n=2$, 3.3% vs. $n=9$, 14.8%, $P=0.027$). There were three cases (4.9%) of Clavien–Dindo Classification greater than or equal to III in group C, fewer than that in group A without statistically significant difference ($P=0.063$). With respect to the length of postoperative hospital stay, compared with group A (16.7 ± 8.5 days), the length of postoperative hospital stay was significantly shorter in both group B (12.5 ± 5.9 days, $P=0.002$) and group C (13.7 ± 6.5 days, $P=0.002$). In groups B and C, there were no significant differences in the biochemical leak, post-pancreatectomy haemorrhage, gastrointestinal haemorrhage, surgical reintervention, and complication-related mortality compared with group A.

Discussion

The findings in the present study have confirmed the safety and effectiveness of the well-established LPD technique. However, the learning curve of LPD is long[12,13]. According to our study, the first 61 cases of LPD were identified as belonging to the learning phase, and 87 cases showed an inflection point beyond the learning curve. Additionally, combined with current reports[14–16], we concluded that surgeons should generally perform 80–100 surgeries to completely pass through the learning curve. Furthermore, complications such as pancreatic fistula, biliary-enteric anastomosis leakage, surgical site infection, and ultimately high mortality rate are more likely to occur at the beginning of the learning curve because of the unsophisticated anastomosis technique. Our previous study revealed that the long LPD learning curve and high incidence of postoperative complications were present at the beginning of the learning curve[5]. The primary reason was an inadequate technique in laparoscopic pancreaticojejunostomy, choledochojejunostomy, and gastrojejunostomy[17]. Consequently, we developed a model and corresponding evaluation system to improve the mastery of gastrointestinal reconstruction, optimize the surgeons' learning curve, and enhance the safety of patients at the beginning of the surgeons' LPD learning curve.

We found the texture of bovine liver section and the bile duct stump suitable for adequately replicating human remnant soft pancreatic stump with a small pancreatic duct in the laparoscopic pancreaticojejunostomy. The texture of porcine jejunum is similar to that of human jejunum. The training model we built for the laparoscopic pancreaticojejunostomy reproduced a real anastomosis scenario well, and the cost of the required practice material was low. In terms of the evaluation system, we determined the proficiency of pancreaticojejunostomy based on the time required for anastomosis. We simulated actual pancreatic ductal pressure by injecting methylene blue into the silicone tube and assessed the accuracy of laparoscopic pancreaticojejunostomy by determining whether there was leakage of methylene blue. This evaluation system can objectively assess the proficiency of laparoscopic pancreaticojejunostomy by clinical practitioners.

We selected patients who required only laparoscopic choledochojejunostomy and laparoscopic suturing of the T-tube incision for laparoscopic choledochojejunostomy training. This model was highly realistic and less complex for surgeon training, which allowed the participants to become fully aware of the texture of the bile duct and the orientation of the bile-intestinal anastomosis. The training session was also very safe for the patient. The incidence of bile leakage and postoperative haemorrhage after the above procedure was very low. Even if there were bile leakage, subsequent surgical site infection was unlikely to occur. The surgeon's proficiency in laparoscopic choledochojejunostomy can be accurately assessed by cumulative experience and the presence or absence of postoperative bile leakage. We chose stapling for gastrojejunostomy in LPD, which was not highly difficult to perform. Familiarity with this technique required only a few palliative short-circuiting surgeries and laparoscopic gastrojejunostomy in cases of major gastrectomy. We also assessed the surgeon's proficiency in laparoscopic gastrojejunostomy by assessing the presence of postoperative gastro-/duodenojejunostomy leakage and gastrointestinal haemorrhage.

The first 61 patients who underwent LPD performed by surgeons B and C were analyzed following completion of the training session. First, the clinicopathological characteristics of patients who underwent surgeries in groups B and C were analyzed. The included cases in groups B and C were similar to those in group A. Consequently, no significant differences were noted in clinicopathological characteristics among groups A, B, and C, which minimized the impact of differences in clinicopathological characteristics on subsequent intraoperative conditions and complication profiles.

As for histopathological characteristics, there were no differences in the pancreas duct size and pancreas texture among groups A, B, and C, indicating that the conditions for laparoscopic pancreaticojejunostomy were similar among three groups. In groups B and C, operative duration was significantly shorter than that in group A, and also shorter than the operative duration previously reported in LPD and RPD[18,19]. After training session, surgeons B and C were more skilled and required less time in the reconstruction of the digestive tract in LPD than before. Simultaneously, by cumulative sum, we analyzed the LPD learning curve of 61 cases in groups B and C. Surgeon B reached the inflection point at case 26, while surgeon C reached the inflection point at case 20, which occurred significantly earlier for both surgeons than for surgeon A, who required 61 cases of LPD experience to reach the inflection point of the learning curve. According to the cumulative-sum result, surgeons B and C passed through the learning curve by accumulating approximately 30–50 cases of LPD, which was significantly earlier than the number shown in our previous studies and the currently recognized 80–100 cases of LPD[5–7]. The above results indicate that the learning curve of LPD can be significantly optimized after completing the LPD training model.

Concerning postoperative complications, group B had a lower incidence in terms of postoperative pancreatic fistulas, biliary-enteric anastomosis leakage and Clavien–Dindo Classification ≥III, *etc.* Group C also had a smaller number of cases than group A with respect to these criteria, although there was no statistically significant difference. We speculated that this situation was because of the relatively small sample size in this study. However, the incidence of postoperative pancreatic fistulas, biliary-enteric anastomosis leakage, Clavien–Dindo Classification greater than or equal to III, and postoperative complications was significantly lower than the industry standard level[8,20–22]. Meanwhile, both groups B and C showed lower rates of surgical site infection and shorter length of postoperative hospital stay compared with group A.

The LPD training system provides an effective approach to optimize the LPD learning curve, reduce the incidence of postoperative complications and shorten the length of hospital stay during the LPD learning phase. However, several limitations have to be acknowledged in the present study. First, two surgeons involved in the training session and experiment had experience in more than 50 cases of OPD and in performing LPD as the first assistant; therefore, the results of this trial reflected the condition of the surgeons with OPD experience following the study rather than that of surgeons who have never been exposed to OPD. However, the authors consider that, for the sake of patient safety, it is essential to have extensive OPD experience to perform LPD and do not recommend surgeons to perform LPD without experience. Second, this is a single-centre study with a relatively small sample size, which decreases statistical power, and some crucial results may have been suppressed and remain to be observed. Although single-centre, our study confirms that the proposed training system could optimize the learning curve of laparoscopic pancreaticojejunostomy and reduce postoperative complications for the benefit of patients. Subsequent multicenter randomized clinical trials may yield more meaningful results for the effective and safe promotion of this surgical method.

Ethics approval and consent to participate

This study had been approved by the Institutional Review Board of Chongqing Xinqiao Hospital (Approval Number—AF/SC-08/1.0; Approval Date—2018.10.16). All patients enroled completed the informed consent form.

Consent

None.

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Author contribution

Y.C.T. is resposible for the study concepts and design, clinical studies, experimental studies, data acquisition and analysis, statistical analysis, manuscript preparation and editing and review; X.H.P. is resposible for the definition of intellectual content, data acquisition; Y.G.H. is resposible for the study design, literature research, statistical analysis; J.L. is resposible for the data analysis; L.Z. is resposible for the guarantor of integrity of the entire study, manuscript review; X.B.H. is resposible for the guarantor of integrity of the entire study, manuscript editing. All authors read and approved the final manuscript.

Conflicts of interest disclosure

There are no potential conflicts of interest to disclose.

Research registration unique identifying number (UIN)

None.

Guarantor

None.

Availability of data and material

All data generated or analyzed during this study are included in this. Further enquiries can be directed to the corresponding author.

Provenance and peer review

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References

[1] Croome KP, Farnell MB, Que FG, *et al*. Total laparoscopic pancreaticoduodenectomy for pancreatic ductal adenocarcinoma: oncologic advantages over open approaches? Ann Surg 2014;260:633–8.
[2] Shi Y, Wang W, Qiu W, *et al*. Learning curve from 450 cases of robot-assisted pancreaticoduocectomy in a high-volume pancreatic center: optimization of operative procedure and a retrospective study. Ann Surg 2021;274:e1277–83.
[3] Wang SE, Shyr BU, Chen SC, *et al*. Comparison between robotic and open pancreaticoduodenectomy with modified Blumgart pancreaticojejunostomy: a propensity score-matched study. Surgery 2018;164:1162–7.
[4] Zhang H, Feng Y, Zhao J, *et al*. Total laparoscopic pancreaticoduodenectomy versus open pancreaticoduodenectomy (TJDBPS01): study protocol for a multicentre, randomised controlled clinical trial. BMJ Open 2020;10:e033490.
[5] Tang YC, Liu QQ, He YG, *et al*. Laparoscopic pancreaticoduodenectomy: a retrospective study of 200 cases and the optimization of the single-center learning curve. Transl Cancer Res 2021;10:3436–47.
[6] Nagakawa Y, Nakamura Y, Honda G, *et al*. Learning curve and surgical factors influencing the surgical outcomes during the initial experience with laparoscopic pancreaticoduodenectomy. J Hepatobiliary Pancreat Sci 2018;25:498–507.
[7] van Workum F, Stenstra MHBC, Berkelmans GHK, *et al*. Learning curve and associated morbidity of minimally invasive esophagectomy: a retrospective multicenter study. Ann Surg 2019;269:88–94.
[8] van Hilst J, de Rooij T, Bosscha K, *et al*. Laparoscopic versus open pancreatoduodenectomy for pancreatic or periampullary tumours (LEOPARD-2): a multicentre, patient-blinded, randomised controlled phase 2/3 trial. Lancet Gastroenterol Hepatol 2019;4:199–207.
[9] Adam MA, Thomas S, Youngwirth L, *et al*. Defining a hospital volume threshold for minimally invasive pancreaticoduodenectomy in the United States. JAMA Surg 2017;152:336–42.
[10] Beane JD, Zenati M, Hamad A, *et al*. Robotic pancreatoduodenectomy with vascular resection: Outcomes and learning curve. Surgery 2019;166: 8–14.
[11] Casadei R, Ricci C, Taffurelli G, *et al*. Prospective validation of a preoperative risk score model based on pancreatic texture to predict postoperative pancreatic fistula after pancreaticoduodenectomy. Int J Surg 2017;48:189–94.
[12] Nickel F, Haney CM, Kowalewski KF, *et al*. Laparoscopic versus open pancreaticoduodenectomy: a systematic review and meta-analysis of randomized controlled trials. Ann Surg 2020;271:54–66.
[13] Fairfield CJ, Connor S, Harrison EM, *et al*. The harms of early cessation of trials on systematic reviews. Lancet Gastroenterol Hepatol 2019;4:667.
[14] Wang M, Peng B, Liu J, *et al*. Practice patterns and perioperative outcomes of laparoscopic pancreaticoduodenectomy in China: a retrospective multicenter analysis of 1029 patients. Ann Surg 2021;273: 145–53.
[15] Qin R, Kendrick ML, Wolfgang CL, *et al*. International expert consensus on laparoscopic pancreaticoduodenectomy. Hepatobiliary Surg Nutr 2020;9:464–83.
[16] Asbun HJ, Moekotte AL, Vissers FL, *et al*. The Miami international evidence-based guidelines on minimally invasive pancreas resection. Ann Surg 2020;271:1–14.
[17] Poves I, Burdío F, Morató O, *et al*. Comparison of perioperative outcomes between laparoscopic and open approach for pancreatoduodenectomy: the PADULAP randomized controlled trial. Ann Surg 2018; 268:731–9.
[18] Watkins AA, Kent TS, Gooding WE, *et al*. Multicenter outcomes of robotic reconstruction during the early learning curve for minimally-invasive pancreaticoduodenectomy. HPB 2018;20:155–65.
[19] Han SH, Kang CM, Hwang HK, *et al*. The Yonsei experience of 104 laparoscopic pancreaticoduodenectomies: a propensity score-matched analysis with open pancreaticoduodenectomy. Surg Endosc 2020;34: 1658–64.
[20] Nagakawa Y, Takishita C, Hijikata Y, *et al*. Blumgart method using LAPRA-TY clips facilitates pancreaticojejunostomy in laparoscopic pancreaticoduodenectomy. Medicine (Baltimore) 2020;99:e19474.
[21] Palanivelu C, Senthilnathan P, Sabnis SC, *et al*. Randomized clinical trial of laparoscopic versus open pancreatoduodenectomy for periampullary tumours. Br J Surg 2017;104:1443–50.
[22] Cai Y, Luo H, Li Y, *et al*. A novel technique of pancreaticojejunostomy for laparoscopic pancreaticoduodenectomy. Surg Endosc 2019;33: 1572–7.