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Comparison of Perioperative and Oncological Outcomes of Hybrid and Totally Laparoscopic Pancreatoduodenectomy

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: Laparoscopic pancreatoduodenectomy (LPD) is a complicated procedure accompanied with high morbidity. Hybrid LPD is usually used as an alternative/transitional approach. This study aimed to prove whether the hybrid procedure is a safe procedure during a surgeon's learning curve of LPD.

Material/Methods: There were 48 hybrid LPD patients and 62 TLPD patients selected from January 2016 to December 2018; their demographics, surgical outcomes, and oncological data were retrospectively collected. Patient follow-up for the study continued until February 2020.

Results: Patient demographics and baseline parameters were well balanced between the 2 groups. Intraoperative conditions, overall operation time was shorter for TLPD compared to hybrid LPD (407.79 minutes versus 453.29 minutes, respectively; *P*=0.035) and blood loss was less in TLPD patients compared to hybrid LPD patients (100.00 mL versus 300.00 mL, respectively; *P*<0.001). There was no difference in transfusion rates between the 2 groups (hybrid LPD 16.7% versus TLPD 4.8%; *P*=0.084). Postoperative outcomes and intensive care unit (ICU) stay was longer in the hybrid LPD patient group (hybrid LPD 1-day versus TLPD 0-day, *P*=0.002) and postoperative hospital stay was similar between the 2 groups (*P*=0.503). Reoperation rates, in-hospital, 30-day mortality, and 90-day mortality rates were comparable between the 2 groups (*P*=0.276, 1.000, 1.000, 0.884, respectively). Surgical site infection, bile leak, Clavien-Dindo classification (CDC) ≥3, delayed gastric emptying, grade B/C postoperative pancreatic fistulae, and grade B/C post pancreatectomy hemorrhage were not different between the 2 groups (*P*=0.526, 0.463, 0.220, 0.089, 0.165, 0.757, respectively). The tumor size, margin status, lymph nodes harvested, and metastasis were similar in the 2 groups (*P*=0.767, 0.438, 0.414, 0.424, respectively). In addition, the median overall survival rates were comparable between the 2 groups (hybrid LPD 29.0 months versus TLPD 30.0 months, *P*=0.996) as were the progression-free survival rates (hybrid LPD 11.0 months versus TLPD 12.0 months, *P*=0.373)

Conclusions: Hybrid LPD was comparable to TLPD. Hybrid LPD could be performed safely when some surgeons first started LPD (during the operative learning curve), while for skilled surgeons, TLPD could be applied initially.

MeSH Keywords: Hand-Assisted Laparoscopy • Laparoscopy • Pancreaticoduodenectomy

Abbreviations: **OPD** – open pancreatoduodenectomy; **LPD** – laparoscopic pancreatoduodenectomy; **TLPD** – totally laparoscopic pancreatoduodenectomy; **RALPD** – robot-assisted laparoscopic pancreatoduodenectomy; **Hybrid LPD** – hybrid laparoscopic pancreatoduodenectomy; **BMI** – body mass index; **ASA** – American Society of Anesthesiologists; **OR** – overall operation; **PHS** – postoperative hospital stay; **ICU** – Intensive Care Unit; **SSI** – surgical site infection; **POPF** – postoperative pancreatic fistulae; **DGE** – delayed gastric emptying; **PPH** – postpancreatectomy hemorrhage; **CDC** – Clavien-Dindo classification; **ISGPS** – International Study Group of Pancreatic Surgery

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Background

Minimally invasive surgery has practiced for many years. Minimally invasive laparoscopic surgery has been widely applied to many different types of operations. However, the application and wide dissemination of minimally invasive surgery for pancreatectomy, particularly pancreatoduodenectomy, has been relatively delayed [1]. Laparoscopic pancreatoduodenectomy (LPD) is a complicated procedure that has not been widely adopted because an advanced level of laparoscopic skill is required. After the first LPD surgery reported [2], there were many studies that showed LPD was a safe and feasible procedure, however, some studies reported that postoperative complications and mortality rates were higher in LPD patients. So, the use of LPD is still being debated [3–7]. Even for surgeons experienced in hepatopancreatobiliary (HBP), a high morbidity rate has not been reported. Technically, PD is composed of 2 major components: resection and reconstruction. LPD techniques include totally laparoscopic pancreatoduodenectomy (TLPD), robot-assisted laparoscopic pancreatoduodenectomy (RALPD), and laparoscopy-assisted PD or the hybrid LPD which combines laparoscopic resection using a mini-laparotomy for specimen extraction with open reconstruction. Hybrid LPD has been used by some surgeons to lower the rate of postoperative complications, especially when they first started to perform LPDs (operative learning curve), and it is often a transitional procedure for surgeons. But there are scant studies focused on hybrid LPDs. So, whether hybrid LPD is a safe and feasible transitional/alternative stage in a surgeon's operative learning curve for TLPD is unclear. The aim of this study was to compare the perioperative and oncology outcomes of hybrid LPD and TLPD, then to verify the safety and feasibility of hybrid LPD on the operative learning curve of surgeons.

Material and Methods

Ethical approval

This study was approved by the Ethics Committee of Chinese PLA General Hospital. All patients provided written informed consent.

Study population

The data of patients was from the Chinese PLA General Hospital. From January 2016 to December 2018, totally 48 patients undergoing hybrid LPD and 62 patients undergoing standard TLPD were selected for this study. All their data were retrospectively collected.

The inclusion criteria were as follows: patients who received adequate preoperative examination and evaluation, the diagnosis was clear and consistent with the indications for pancreatoduodenectomy, and the patients had undergone either a standard TLPD or hybrid LPD surgery.

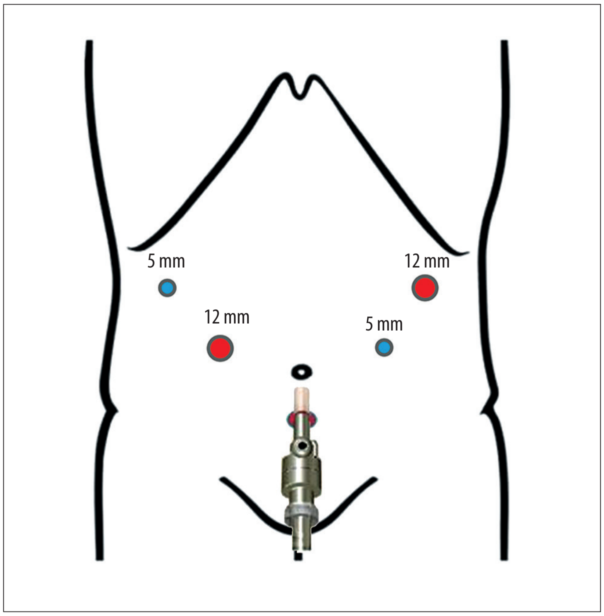

Figure 1. The trocar distribution.

The exclusion criteria were as follows, surgery: 1) combined with other abdominal organ resection or tumor resection; 2) combined with portal vein or hepatic artery invasion; 3) conversed to open surgery during resection period; 4) combined with other treatment methods, such as radioactive particle implantation, etc.; 5) pylorus-preserving pancreatoduodenectomy.

Surgical procedure

Patients were under general anesthesia and in a horizontal, head-up position. Pneumoperitoneum pressure was 12–14 mmHg. Trocar distribution was the same in the 2 approaches (Figure 1), like the letter "V". The resection process followed a Chinese guideline and was the same in both approaches. The process was as follows: 1) Kocher dissociation; 2) stomach transection; 3) dissect the hepatoduodenal ligament, then cholecystectomy was performed and transection of the common bile duct; 4) pancreas transection; 5) jejunum transection; 6) dissection of superior mesenteric vein (SMV)-portal vein system; 7) dissection of superior mesenteric artery (SMA)-celiac trunk system and transection of uncinate process. In the hybrid LPD group, the reconstruction period was performed via an upper abdomen central mini-laparotomy (8–10 cm) and the anastomosis methods of open PD were used. In the TLPD group, during reconstruction period patients received the standard TLPD approach, using the anastomosis methods under laparoscopy. All operations were pancreaticojejunostomy and no pancreaticogastrostomy was performed.

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Two to 4 abdominal drainage tubes were placed in front of and/or behind the pancreatoenterostomy, and in front of and/or behind the choledochoenterostomy.

Study design

This was a retrospective study. The patients were categorized into 2 groups based on the operation they received. Finally, the hybrid LPD group included 48 patients, and the TLPD group included 62 patients.

Surgical indications were the same for both TLPD and hybrid LPD cases: benign and borderline malignant pancreatic tumor, distal cholangiocarcinoma (T1–T3), ampullary tumor, pancreatic ductal adenocarcinoma (T1–T3), and duodenal papillary tumor.

Nearly all (except 2) hybrid LPD operations were performed by Dr. Shi, a specialized hepatopancreatobiliary (HBP) surgeon and chief physician of the Department of Hepatobiliary Surgery at Chinese PLA General Hospital. Other HBP surgeons at the Chinese PLA General Hospital were also well experienced and skilled and had performed adequate pancreatic and laparoscopic surgeries. Standards for PD remained constant, study surgeons had the same surgical experience, and the surgical processes were nearly the same. Perioperative management and treatment of postoperative complications were consistent and used standardized PD procedures. All cases in both groups involved the initial learning curve period operation of each surgeon.

Measurements

Baseline parameters included age, sex, body mass index (BMI), past medical history (especially for hypertension, diabetes, cardiovascular and cerebrovascular diseases), past abdominal surgery history, personal history (smoking and drinking habits), American Society of Anesthesiologists (ASA) score, pancreatic texture, preoperative jaundice (≥21 umol/L) and preoperative CA 19-9 ascend (≥37U/mL). The pathologic data included tumor location, type, size, margin status, and lymph node(s) harvested and positive. Intraoperative data included overall operation time, blood loss, and overall operation transfusion. Short-term postoperative outcome parameters included postoperative hospital stay (PHS), intensive care unit (ICU) stay, reoperation rates, in-hospital mortality, 30-day mortality, 90-day mortality, and postoperative morbidity. Postoperative morbidity refers to surgical site infection (SSI), bile leak, postoperative pancreatic fistulae (POPF), delayed gastric emptying (DGE), or post pancreatectomy hemorrhage (PPH). Complications were recorded following the Clavien-Dindo classification system [8]. Pancreatic fistulae (POPF), delayed gastric emptying (DGE), and postpancreatectomy hemorrhage (PPH) were defined according to the International Study Group of Pancreatic Surgery (ISGPS) definitions [9–11]. We conducted postoperative follow-up of all patients through February 2020, and reported the survival and recurrence of the study cancer patients.

Statistical analyses

Continuous variables were expressed as mean±standard deviation or median (minimum and maximum values) depending on the data distribution. We used *t*-test for continuous variables of normal distribution. Non-normally distributed continuous variables were analyzed using the Mann-Whitney U test. Categorical variables were tested using the chi-square test or the Fisher's exact test. Kaplan-Meier curve was used to analyze the overall survival and progression-free survival rates. Statistical analysis was executed with SPSS Software 20.0 (IBM SPSS Statistics, IBM Corporation, Chicago, IL, USA). A P value of <0.05 (2-tailed) was considered statistically significant.

Results

General characteristics of patients

As shown in Table 1, patient demographics and baseline parameters were well balanced between the 2 groups. There were 28 males and 20 females in the hybrid LPD group and 33 males and 29 females in the TLPD group (P=0.593). Mean age of the hybrid LPD group was 57.8 years and the mean age in the TLPD group was 57.0 years (P=0.718). Mean BMI of the hybrid LPD group was 24.2 kg/m^2 and the mean BMI of the TLPD group was 23.1 kg/m^2 (P=0.058). There were no differences in ASA score, past medical history, personal history, or past abdominal surgery history between the 2 groups (P=0.185, P=0.202, P=0.790, and P=0.271 respectively). Pancreatic texture, preoperative jaundice, and preoperative CA 19-9 level were comparable between the 2 groups (P=0.914, P=0.900, and P=0.189 respectively).

Perioperative outcomes

Table 2 shows the perioperative characteristics of the 2 groups. There was no death during operation in the 2 groups. The mean overall operation time was a little longer in the hybrid LPD group compared to the TLPD group (455.3 minutes versus 407.8 minutes, respectively, P=0.035). Blood loss in the hybrid LPD group was more than in the TLPD group (median 300 mL versus 100 mL, respectively; P<0.001), and transfusion rate tended to be higher in the hybrid LPD group (16.7% versus 4.8%, respectively; P=0.084). ICU stay was shorter in the TLPD group (P=0.002) and postoperative hospital stay was similar in both groups (P=0.503). Regarding perioperative safety and postoperative complications, reoperation rates (hybrid LPD 14.6% versus TLPD 6.5%), the in-hospital mortality (hybrid LPD 6.3%

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Table 1. Demographics and baseline parameters.

Variables	Hybrid LPD (n=48)	TLPD (n=62)	Statistical values	*P*
Sex (M/F)	28/20	33/29	0.286	0.593
Age (years)	57.79±8.89	57.02±12.62	–0.362	0.718
BMI (kg/m²)	24.23±3.21	23.09±2.99	–1.915	0.058
ASA (%)			3.370	0.185
I	0 (0.0)	2 (3.3)		
II	45 (93.8)	52 (85.2)		
III	3 (6.3)	7 (11.5)		
Past medical history			1.626	0.202
Yes	22 (45.8)	21 (33.9)		
No	26 (54.2)	41 (66.1)		
Personal history			0.071	0.790
Yes	19 (39.6)	23 (37.1)		
No	29 (60.4)	39 (62.9)		
Histories of abdomen surgery			1.211	0.271
Yes	9 (18.8)	7 (12.1)		
No	39 (81.2)	51 (87.9)		
Pancreatic texture (n%)			0.012	0.914
Soft	22 (47.8)	29 (46.8)		
6Hard	24 (52.2)	33 (53.2)		
Preoperative jaundice (n%)			0.016	0.900
≥21	30 (63.8)	39 (65.0)		
<21	17 (36.2)	21 (35.0)		
CA19-9 (n%)			1.726	0.189
≥37	26 (63.4)	28 (50.0)		
<37	15 (36.6)	28 (50.0)		

LPD – laparoscopic pancreatoduodenectomy; TLPD – totally laparoscopic pancreatoduodenectomy; BMI – body mass index; ASA – American Society of Anesthesiologists.

versus TLPD 8.1%), 30-day mortality (hybrid LPD 6.3% versus TLPD 8.1%) and 90-day mortality (hybrid LPD 10.4% versus TLPD 11.3%) were comparable between the 2 groups (*P*=0.276, *P*=1.000, *P*=1.000, *P*=0.884, respectively). DGE tended to be less in the hybrid LPD group; *P* was nearly to 0.05 at *P*=0.089. SSI as well as bile leak, CDC ≥3, grade B/C POPF, and grade B/C PPH were not different between the 2 groups (*P*=0.526, *P*=0.463, *P*=0.220, *P*=0.165, *P*=0.757, respectively).

Short-term and long-term oncologic outcomes

Table 3 shows the pathologic and long-term characteristics. The hybrid LPD group showed comparable short-term oncologic outcomes to those of the TLPD group. No significant differences were found in tumor type, tumor size, number of lymph nodes harvested, and positive and margin status (*P*=0.361, *P*=0.767, *P*=0.414, *P*=0.424, *P*=0.438, respectively), but margin status R+ was a little higher in the hybrid LPD group compared to the TLPD group (6.3% versus 1.6%, respectively). Figure 2 shows the overall survival rates of the 2 groups; there was no difference in the 2 groups (*P*=0.996). Figure 3 shows the progression-free survival rates: the hybrid LPD group progression-free survival rate was 11.0 months versus TLPD progression-free survival rate of 12.0 months, *P*=0.373.

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Table 2. Perioperative characteristics.

Variables	Hybrid LPD (n=48)		TLPD (n=62)		Statistical values	P
OR time (min)	453.29±73.48		407.79±143.96		−2.140	0.035
Blood loss (mL)	300	(100–1200)	100	(20–1800)	−5.495	<0.001
Transfusion (n%)	8	(16.7)	3	(4.8)	2.994	0.084
ICU (days median range)	1	(0–13)	0	(0–8)	−3.027	0.002
Postoperative hospital stay (days median range)	13.5	(3–32)	12.5	(5–72)	−0.670	0.503
Reoperation rates (n%)	7	(14.6)	4	(6.5)	1.187	0.276
In-hospital mortality (n%)	3	(6.3)	5	(8.1)	<0.001	1.000
30-day mortality (n%)	3	(6.3)	5	(8.1)	<0.001	1.000
90-day mortality (n%)	5	(10.4)	7	(11.3)	0.021	0.884
SSI (n%)	10	(20.8)	10	(16.1)	0.402	0.526
Bile leak (n%)	2	(4.2)	6	(9.7)	0.538	0.463
CDC (n%)					1.507	0.220
0–2	33	(68.8)	49	(79.0)		
3/4	12	(25.0)	8	(12.9)		
5	3	(6.2)	5	(8.1)		
DGE (n%)					2.899	0.089
A/No	47	(97.9)	54	(87.1)		
B/C	1	(2.1)	8	(12.9)		
POPF (n%)					1.925	0.165
A/No	36	(75.0)	53	(85.5)		
B/C	12	(25.0)	9	(14.5)		
PPH (n%)					0.096	0.757
A/No	40	(83.3)	53	(85.5)		
B/C	8	(16.7)	9	(14.5)		

LPD – laparoscopic pancreatoduodenectomy; TLPD – totally laparoscopic pancreatoduodenectomy; OR – overall operation; ICU – Intensive Care Unit; SSI – surgical site infection; CDC – Clavien-Dindo classification; DGE – delayed gastric emptying (DGE); POPF – postoperative pancreatic fistulae; PPH – post pancreatectomy hemorrhage.

Discussion

There have been many studies that have considered LPD to be a safe and feasible procedure. But other studies have shown LPD had no advantage over open PD at the current level of evidence. To date, we could not reach a consensus on whether we should adopt LPD for our patients, and we were unable to identify the indications for LPD accurately. This was most likely because of the complexity of the relevant anatomy, the difficulty in the reconstruction phase, and the high morbidity rate even for open PD. However, there has been agreement among experts that LPD requires an operative learning curve to achieve a stable procedural phase, with 30 cases, 50 cases, or more needed to achieve a stable procedural phase [12,13]. During the operative learning curve, especially for the initial operative learning period, the morbidity and mortality rates are relatively high, which is not acceptable to surgeons or patients. So, an alternative/transitional approach is much needed, such as hybrid LPD procedure, which is defined as a combined laparoscopic resection with mini-laparotomy for the reconstruction segment. Performing minimally invasive PD using a hybrid method in the initial operative learning curve phase has been reported to help safely shift surgeons' skills to a totally laparoscopic method [13–15]. van Hilst et al. reported that no benefit was found in the learning curve for surgeons for LPD with open reconstruction compared to TLPD [16]. However, there is still controversy in this area of study. Studies that focus on hybrid LPD directly compared to hybrid LPD with TLPD are rare. So, there is little data as to whether hybrid LPD is suitable as a transitional procedure, or whether it is superior to performing TLPD immediately. To explore the efficacy of LPD, we retrospectively compared hybrid LPD with TLPD, assessing

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Table 3. Pathologic characteristics and long-term outcomes.

Variables	Hybrid LPD (n=48)		TLPD (n=62)		Statistical values	*P*
Histology (n%)					4.348	0.361
Pancreatic head cancer	10	(20.8)	15	(24.2)		
Periampullary cancer	15	(31.3)	23	(37.1)		
Cholangiocarcinoma	14	(29.2)	12	(19.4)		
Benign tumor of pancreatic head	7	(14.6)	5	(8.1)		
Others	2	(4.2)	7	(11.3)		
Tumor size (cm)	2.61±1.12		2.71±2.05		0.297	0.767
Lymph nodes harvested	9.40±5.83		8.42±6.16		–0.820	0.414
pN (n%)					0.640	0.424
N+	13	(28.9)	13	(22.0)		
N0	32	(71.1)	46	(78.0)		
Margin status (n%)					0.601	0.438
R+	3	(6.3)	1	(1.6)		
R0	45	(93.8)	61	(98.4)		
Median survival time (month)	29	(1–36)	30	(1–49)	<0.001	0.996
Progression-free survival (month)	11	(1–36)	12	(1–49)	0.792	0.373

LPD – laparoscopic pancreatoduodenectomy; TLPD – totally laparoscopic pancreatoduodenectomy.

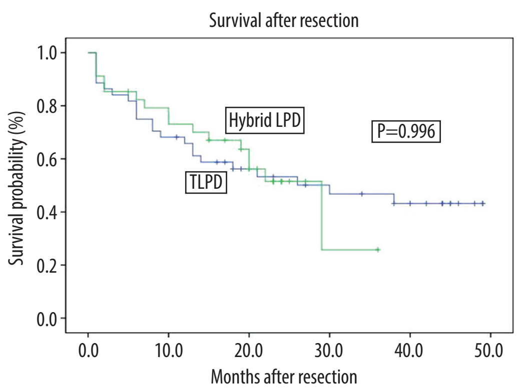

Figure 2. Kaplan-Meier survival curves of overall survival rates.

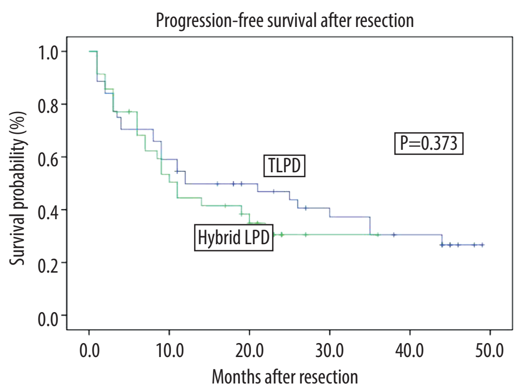

Figure 3. Kaplan-Meier survival curves of progression-free survival rates.

perioperative and radical outcomes. All cases were "initial experienced cases", in other words, we compared an initial learning curve period of hybrid LPD and an initial learning curve period of TLPD. Unfortunately, compared to TLPD, no significant benefits of the hybrid LPD method were found in our study.

In our study, the overall operation time was shorter in TLPD patients (hybrid LPD operation time was 453.29 minutes versus TLPD 407.79 minutes). Many other studies have shown longer operation time for LPD compared to open PD [4,5,17,18]. Consideration of surgeons' experiences has been suggested as a possible reason for results in previous studies. In our study, operation time was slightly longer in hybrid LPD patients, which was consistent with some previous studies [16,19]. These differences are challenging to reconcile in our study, as the laparoscopic resection process was similar in the 2 approaches, so the time needed in this period should be similar too. The first possible reason could be that for the hybrid LPDs, reconstruction was operatively by mini-laparotomy (5–10 cm), for standard open PD, an operative incision is usually long (20–30 cm), for TLPD, laparoscopic reconstruction. Mini-laparotomy limits surgeons' surgical operation and surgical field compared to standard open PD, then leads to a longer operation time. The second potential factor might be that as the reconstruction methods are not the same between open and laparoscopic reconstruction, this could be a possibly influence on the operation time. Thirdly, the time of closing of the abdominal incision is different in the different procedures, and thus might account for the differences. Fourthly, in clinical practice, as hybrid LPD is similar to an LPD that converts to open surgery to some extent, it takes more time to remove the laparoscopic instruments, replace them with open instruments, and then performed open reconstruction. Other possible reasons such as tumor size, histories of abdomen surgery, were well balanced in the 2 groups in our study, and there was no difference in indications, so these reasons can be excluded from consideration.

We observed reduced blood loss and transfusion rates in TLPD patients in our study. A systematic literature review compared TLPD, RAPD, and hybrid LPD, and showed increased blood loss in hybrid LPD patients [19]. Van Hilst found hybrid LPD was superior in terms of blood loss [16]. This was also a challenging result to consider. Laparoscopic surgery is characterized by a magnified field of vision, fine operative performance, and more detailed vascular treatment. So usually, LPD would be expected to reduce blood loss compared to open PD. Surgical experience suggests blood loss mainly occurs in the resection phase, and since hybrid LPD is nearly the same as TLPD during the resection phase, we would expect the reconstruction period to also contribute some blood loss, and that the TLPD reduced blood loss in the reconstruction phase would be comparable with that of open reconstruction; and the surgical process and skills might differ more or less in different surgeons and when more cases are involved.

We found that while ICU stay was shorter in TLPD patients, postoperative hospital stay was not different between the 2 groups. These are very important advantages of LPD over open PD. While the longer ICU stay for the hybrid LPD patients in our study might have been influenced by the number of cases and by postoperative management differences, the result suggests that although PD is a large trauma surgery, postoperative ICU stay might not be necessary for most PD patients. While the consensus is that minimal surgery means faster recovery, this might not apply to minimally invasive PD. However, van Hilst et al. reported no difference between groups in time to functional recovery [20]. Choi et al. found no difference in postoperative time-dependent inflammatory scores and white blood cell (WBC) count [21]; our study verified these finding. Differences from other minimally invasive surgeries in delayed discharge and postoperative recovery of PD cases is mainly attributed to postoperative complications, not only for operative incision but also postoperative inflammatory response. These 2 complications were comparable in our study and postoperative hospital stay was also similar in the 2 groups.

Postoperative DGE is also a big problem, it prolongs hospital stay, decreases the quality of life, and diminishes nutritional status. A number of studies of LPD cases found a reduction of surgical DGE in LPD patients [5,18,22,23]. A meta-analysis found that reduced use of analgesic drugs, shortened time of abdominal cavity exposure, and earlier postoperative activities were considered to be the main reasons for earlier gastrointestinal recovery from minimally invasive PD [24]. Marjanovic et al. found that a reduction in postoperative bowel edema in patients undergoing LPD might also be a potential mechanism [25]. As for hybrid LPD, the reconstruction is done via mini-laparotomy, very similar to the reconstruction done in open PD. Thus, these aforementioned factors should be better in TLPD cases. In our study, although no statistical difference was found between LPD and TLPD, DGE tended to be less in hybrid LPD patients. Pang et al. also found that although there was no statistical difference, open PD tended to decrease DGE [26]. DGE can be caused by many factors, and although the mechanism is still unclear, different gastrointestinal anastomosis, different personal situation, and long-time pneumoperitoneum might also contribute to DGE. Further study in this area is needed.

POPF, bile leak, SSI, and complications of CDC ≥3 are mainly attributed to the reconstruction phase. Technical difficulties during reconstruction under laparoscopic and high complications rates limit the application of LPD. This is an important reason why hybrid LPD procedures are considered. Some literature reviews have shown a higher POPF rates in hybrid LPD patients compared to patients receiving other LPD procedures [19,27]. A study that involved 150 cases in which 67% of cases had hybrid LPD, found that complication rates did not differ between the initial operative learning curve phase and stable operative procedure periods [12]. Thus, whether a hybrid LPD could potentially lower the POPF, bile leak, and some other lethal complications compared to TLPD, at least in the initial learning curve period is unclear. The technological complexity of gastroenterologic, pancreatic, and biliary anastomosis under laparoscopy contributes to complications after LPD. Because hybrid LPD is similar to open PD during the reconstruction phase, one can assume application of this technology would result in a similar complication rate. But in our study, although there were no differences in the aforementioned complications, the rates tended to be worse in hybrid LPD patients, except for bile leak. While a mini-laparotomy might limit the surgeon, through loss of adequate field, hand performance, and other advantages of open PD, on the other hand, there would be a loss of the superior factors of reconstruction under laparoscopy, such as precise operation and

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enlargement of vision. Prevention of bowel wall edema might be one advantage of minimally invasive surgery, as it leads to faster anastomotic healing [25]; hybrid LPD might lose this advantage. Furthermore, these complications might be related to a patient's personal situation, such as obesity, pancreatic texture, width of pancreatic duct and common bile duct, and so on. Whether open PD could lower POPF rate compared to LPD is still controversial, let alone whether this would be the case for hybrid LPD. So carefully consideration is required as to whether hybrid LPD via open reconstruction could lower the complications compared to TLPD.

The safety of hybrid LPD is the most important factor to consider. The grade B/C PPH rates, reoperation rates, in-hospital mortality rates, 30-day mortality rates, and 90-day mortality rates of the 2 groups in our study were comparable, while reoperation rates tended to be higher in the hybrid LPD patient group. PPH includes intragastric bleeding and abdominal bleeding and was the main reason for reoperation and patient death in both our study groups. Different studies have debated these issues [4,5,16,17,28,29]. According to the time of occurrence, abdominal bleeding mostly happens due to POPF, SSI, and other complications. So, postoperative complications might seem higher in hybrid LPD patients in our study, which can lead to PPH and reoperation. Van Hilst et al. [16] and Boggi et al. [19] found no benefit of lower postoperative complications, PPH, or mortality in hybrid LPD patients, which was consist with our study findings. Our results showed a comparable safety assessment for hybrid LPD and TLPD; thus, if surgeons want to gain LPD experience by performing hybrid LPD when they first start performing LPDs, our study findings would support this. If some surgeons find a high morbidity rate and mortality rate when performed TLPDs, they might want to adopt the hybrid LPD to complete their operative learning curve more safely; thus, our study findings might be disappointing for some surgeons.

In terms of radical oncologic resection rates, our study found no difference in lymph nodes harvested, lymph node metastasis or R0 resection rates in patients undergoing hybrid LPD versus TLPD. But we did find the margin status R+ rates in the hybrid LPD group was a little higher. Some other research has shown better short-term oncologic outcomes for LPD: reduced R1 resection rates and a higher number of lymph nodes harvested in LPD patients [4,5,23,30,31]. One characteristic of laparoscopy is that as the vision is enlarged, the performance is more finely detailed, so R0 status and lymph node harvest are better. In our study, in terms of long-term outcomes, the overall survival rates and progression-free survival rates were comparable between the 2 groups. Although not significantly different, tumor type was not the same in both groups. Different tumors have different prognosis, so this might have influenced the outcomes in our study. The sample size was too small for us to compare the overall survival rates for each specific tumor type in the 2 groups; thus, a bias is possible. On the other hand, all the short-term and long-term outcomes of our study were mainly influenced by the performance during the resection period, so if the surgical skills of surgeons were the same and the sample size was large enough, there ought to be no difference between the 2 approaches. So, the difference might just be due to not having enough cases to study.

To date, LPD surgery has been performed more and more often, and hybrid LPD has been naturally applied by many surgeons as a kind of LPD, especially in the initial period of their operative LPD learning curve. Our study did not show a supportive finding for use of hybrid LPD. But we did note that hybrid LPD had a positive effect on optimizing the surgical process, enhancing laparoscopic skills and the ability to deal with sudden bleeding during resection. As one step to TLPD, it could be considered a good foundation for further TLPD operation. Thus, we should recognize its value to some extent. On the other hand, we also note that this procedure is just a transitory stage, not a final objective, and hybrid LPD will not let a surgeon gain the skills and experience of reconstruction under laparoscopy. Nieuwenhuijs et al. found that in their first learning curve cases, TLPD resulted in high morbidity and mortality, but when they performed some hybrid LPDs, the morbidity and mortality was much better, thus, they highly affirmed the value of performing hybrid LPD during the operative learning curve period [15]. While in our study, we did not find the same benefits of hybrid LPD compared to TLPD.

Limitations of this study were as follows: firstly, the number of cases involved was small; this was a relatively small sample size study. Secondly, this was a retrospective matched pair study. Thirdly, operations were not done by the same surgeon, so there might exist a possible variation in the operative technique and perioperative management of patients.

Conclusions

In conclusion, the application of hybrid LPD techniques is still being debated. In our study, no difference was found in most parameters. But hybrid LPD had longer operation time, more blood loss, and tended to have higher reoperation and POPF rates. Although no significant benefit was found for hybrid LPD, hybrid LPD could become a safe alternative/transitional approach to TLPD during a surgeon's learning curve initial phase, while for experienced and skilled surgeons, TLPD could be performed immediately and initially.

Conflict of Interest

None.

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