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Robot-assisted laparoscopic pancreaticoduodenectomy versus open pancreaticoduodenectomy – A comparative study

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ABSTRACT

Background: Traditionally, pancreatic surgery is considered as one of the most complex surgeries. The recently developed robotic technology allows surgeons to perform pancreaticoduodenectomy. A comparative study was undertaken to study outcomes between robotic approach and open approach.
Methods: A consecutive patients underwent pancreaticoduodenectomy (robotic approach, $n = 20$; open approach = 67) between January 2000 and February 2012 at a single institution were analyzed.
Results: The robotic group had a significantly longer operative time (mean, 491.5 vs. 264.9 min), reduced blood loss (mean, 247 vs. 774.8 ml), and shorter hospital stay (mean, 13.7 vs. 25.8 days) compared to the open group. Open conversion rate was 5%. There was no significant difference between the two groups in terms of overall complication rates, mortality rates, R0 resection rate and harvested lymph node numbers.
Conclusions: This study showed that robot-assisted laparoscopic pancreaticoduodenectomy was safe and feasible in appropriately selected patients. However, it is too early to draw definitive conclusions about the value of robot-assisted laparoscopic pancreaticoduodenectomy. In light of remaining uncertainties regarding short-term and long-term outcome, caution should be exercised in the assessment of the appropriateness of this operation for individual patient.

1. Introduction

Traditionally, pancreatic surgery is considered as one of the most complex surgery among the abdominal procedures. This is an operation with high morbidities, typically in the range of 40%.[1–3] As a result, minimally invasive surgery development in pancreatic surgery is also lag behind that in other gastrointestinal organs. Recently, there has been growing interest in the ability to perform complex pancreatectomy using the laparoscopic approach. These advanced minimally invasive surgeries require surgeons to have highly experienced laparoscopic skills. Therefore, the development is slow also. Since the first laparoscopic pancreaticoduodenectomy was reported in 1994, only limited series of laparoscopic pancreaticoduodenectomy showing their feasibility, safety, and adequacy have been published.[4–8] The recently developed surgical robotic systems can overcome many of the limitations and drawbacks of conventional laparoscopic approach. This may fasten the minimally invasive surgery development of pancreatectomy. Currently, reports on robot-assisted laparoscopic pancreaticoduodenectomy are scarce still.[9,10]

This nonrandomized comparative study aimed to evaluate the outcomes between robot-assisted laparoscopic pancreaticoduo denectomy and open pancreaticoduodenectomy.

2. Materials and methods

A consecutive series of patients who underwent robot-assisted laparoscopic pancreaticoduodenectomy and open pancreaticoduodenectomy for malignant or benign pathologies at the Department of Surgery, Pamela Youde Nethersole Eastern Hospital between January 2000 and February 2012 were analyzed. In May 2009, we started performing robot-assisted laparoscopic pancreatic surgery. From May 2009 to February 2012, 20 patients underwent robot-assisted laparoscopic pancreaticoduodenectomy. During this period, two patients with inoperable carcinoma of pancreas received robot-assisted laparoscopic palliative biliary and gastric bypass after staging laparoscopy. From January 2000 to February 2012, 67 patients underwent open pancreaticoduodenectomy.

The da Vinci® S Surgical System (Intuitive Surgical Inc., Sunnyvale, CA) was used for all robot-assisted procedures. Robotic procedures are performed by experienced surgeons possessing a combination of advanced laparoscopic skills and extensive experience with open pancreatic surgery. The selection criteria for robot-assisted laparoscopic pancreaticoduodenectomy was those pancreatic/periampullary tumors not accompanied by vascular invasion and American Society of Anesthesiologists score (ASA) ≤ 3. All patients were informed about the nature of the procedure, and consent was obtained before surgery. The outcome measures included operating time, blood loss, number of lymph nodes identified in the surgical specimen, margin of resection, length of post-operative hospital stay, and morbidity and mortality rates. The definition of pancreatic fistula was a drain output of any

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measurable volume of fluid on or after post-operative day 3 with an amylase content greater than 3 times the serum amylase activity.

2.1. Procedure for robot-assisted laparoscopic pancreaticoduodenectomy

The patient is placed on a split-leg table in the supine position. The patient is positioned in reverse Trendelenberg position. The robotic system is positioned at the head of the patient, and the assistant surgeon is positioned at the side of patient. The operation begins with a staging laparoscopy and laparoscopic ultrasound using a 12-mm trocar placed in the sub-umbilical site. If no distant metastases or portal vein/superior mesenteric vein invasion, the remaining trocars (one assistant port 12 mm and three 8 mm ports) are placed. Port placement is illustrated in Fig. 1. The camera is placed in the sub-umbilical port. All the rest three arms of the robot are utilized, with the third robotic arm used for retraction and exposure. The assistant 12 mm port allows the assistant surgeon to pass needles, and manage the suction-irrigator, clip appliers, and endostapler as needed.

Cholecystectomy is performed first. The hepatic flexure is then mobilized. A wide Kocher maneuver is also performed with mobilizing the transverse duodenum from the ligament of Trietz from the right side of the table beneath the mesenteric vessels. After Kocher maneuver is completed, the common bile duct is freed from the portal vein and the hepatic artery. The bile duct is transected higher above the cystic duct junction. The common hepatic artery is identified and dissected, followed by dissection and ligation of the gastroduodenal artery. The gastroduodenal artery is double clipped and divided near its origin (Fig. 2). Porta lymph node dissection was performed also.

After portal dissection, the distal stomach is identified and cleared of mesentery along its greater and lesser curves with the Ligasure (Covidien, Boulder, CO, USA). The nasogastric tube is withdrawn, and the stomach is transected with an endostapler (Covidien, Norwalk, CT, USA). The proximal jejunum segment is then identified. The proximal jejunal loop is prepared by further mobilizing the ligament of Treitz, and several vessels are taken with the coagulative scissors and Ligasure (Fig. 3). The jejunum is divided distal to the ligament of Treitz using an endostapler.

The greater omentum is incised to allow entry into the omental bursa. The anterior plane of the superior mesenteric vein is exposed, and the tissue between this plane and the dorsal plane of the pancreas is freed, followed by tunneling between the pancreas and the portal vein (Fig. 4). The tunneled pancreas is then transected (Fig. 5). The pancreas is mobilized from the lateral border of the superior mesenteric vein (SMV)-portal vein working in a caudal to cephalic direction.

As in open approach, upon completion of the pancreaticoduodenectomy, the proximal 2–3 cm of the pancreatic body remnant was mobilized in preparation for the pancreaticojejunostomy (PJ) anastomosis. The dissected segment of the jejunum is pulled out from the dorsal plane of the mesentery to the right side. PJ anastomosis, hepaticojejunostomy, and gastrojejunal anastomosis are performed in this order. If the pancreatic duct is small ($</=$ 3 mm), 2-layers end-to-side dunking technique of PJ anastomosis is performed. If the pancreatic duct is dilated ($>$3 mm), 2-layers end-to-side duct-to-mucosal anastomotic technique (Fig. 6) is performed. Internal pancreatic ductal stenting is used. The stent is not secured. The reconstruction is completed in each patient using an end-to-side hepaticojejunostomy (Fig. 7), and a side-to-side gastrojejunostomy. The specimen is extracted into an endobag through a Pfannenstiel incision. Two silicone drains are placed near pancreaticojejunostomy and hepatico-jejunsotomy at the end of the procedure.

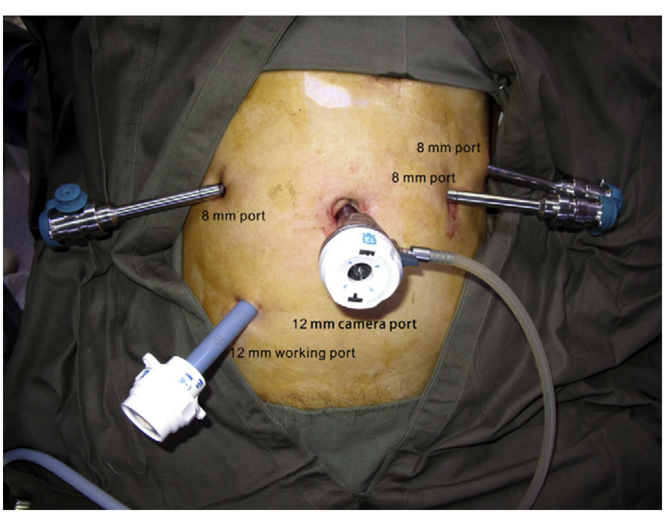

Fig. 1. Port site.

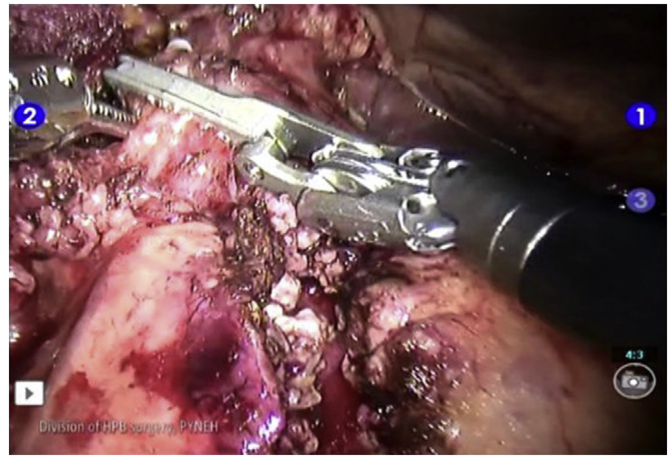

Fig. 2. Clipping of gastroduodenal artery.

2.2. Statistical method

Continuous variables were expressed as mean ± standard deviation (SD) and were compared using the Student's *t* test. Categorical variables were compared using the χ^2 test or Fisher's exact test. *p*-Value less than 0.05 was considered statistically significant.

3. Results

During the study period, 20 patients underwent robot-assisted laparoscopic pancreaticoduodenectomy and 67 patients underwent open pancreaticoduodenectomy. The two groups were well matched for age, gender, tumor size, pathologies, and type of anastomoses. Demographic characteristics of the patients, and operative details were shown in Table 1. Malignant cases accounted for 75% of patients in the robotic group and 79.1% of patients in the open group. Both groups had no vascular invasion identified at time of surgery.

Intraoperative and post-operative outcomes were shown in Table 2. The robotic group had a significantly longer operative time (mean, 491.5 vs. 264.9 min), reduced blood loss (mean, 247 vs. 774.8 ml), and a shorter hospital stay (mean, 13.7 vs. 25.8 days) compared to the open group. In the robotic group, the operating time of the first 10 and the second 10 patients was analyzed. There were no significant differences (521.1 ± 122.9 min vs. 461.9 ± 40 min) ($p = 0.16$).

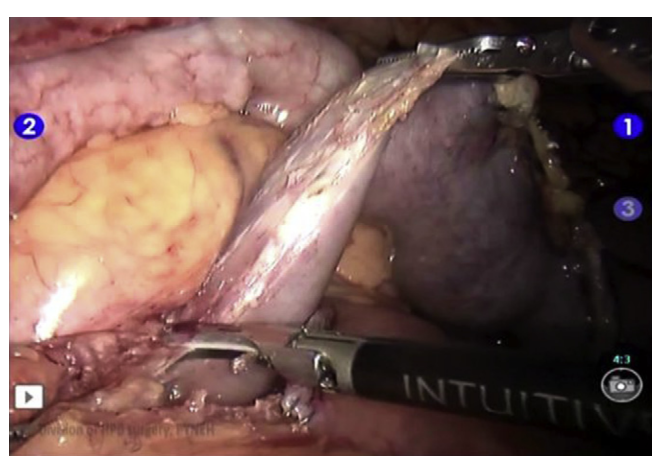

Fig. 3. Mobilization of proximal jejunum.

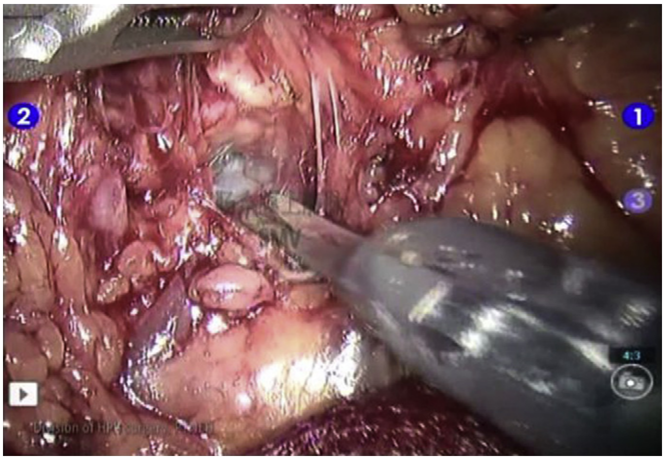

Fig. 4. Tunneling between pancreatic neck and portal vein.

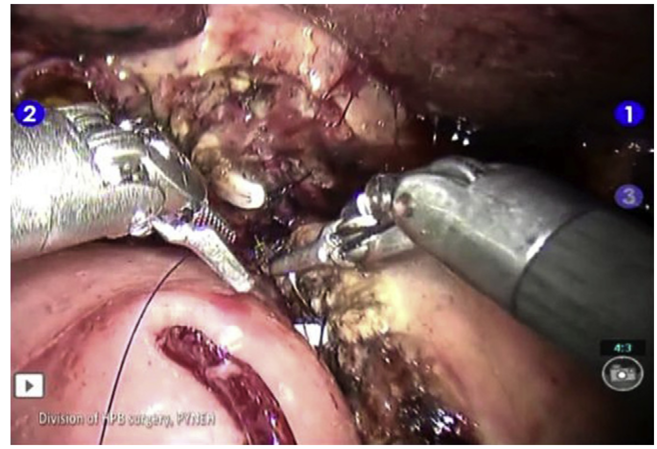

Fig. 6. Pancreaticojejunostomy (duct-to-mucosa approach).

One patient in the robotic group required conversion to open surgery (5%) because of difficulties in dissecting the pancreatic head and neck from the SMV/portal vein in a patient with chronic pancreatitis. There was no significant difference between the two groups in terms of overall complication rates (50 vs. 49.3%), mortality rates (0 vs. 3%). The length of post-operative stay for the robotic group was significantly shorter than for the open group (mean, 13.7 vs. 25.8 days).

Seven patients in robotic group developed PJ leakages/fistulas, representing 35%. All were managed conservatively with octreotide and antibiotics coverage. This meant simply keeping the drains in place and measuring the output on a daily outpatient basis. This group of patients, except one mentioned below, did not require further surgical treatment, and the drains were removed when output was minimal. In the open group, 12 patients (17.9%) developed PJ leakages/fistulas, and only one of the 12 patients needed reoperation due to PJ leakages/fistulas.

A total of 2 patients in the robotic group required reoperation. One patient suffered from pseudoaneurysm over replaced right hepatic artery due to infective complication of PJ leakage/fistula. Transarterial embolization was failed. Open exploration for hemostasis was performed. The other patient was reoperated for right ascending colon ischemia due to inadvertent injury to its blood supply. Right hemi-colectomy was performed.

Pathology outcomes were shown in Table 1.

4. Discussion

Pancreaticoduodenectomy remains the greatest challenge for pancreatic surgeons and entails not only extensive dissection around major blood vessels but also the formation of complex and multiple anastomoses. Recently, Gumbs et al. reviewed 285 patients underwent conventional laparoscopic pancreaticoduodenectomy reported in the medical literature so far.[10] 87% were performed totally laparoscopically, and 13% were performed with a hand-assisted approach. The rate of conversion to an open procedure was 9%. Estimated blood loss was 189 ml. Average length of stay was 12 days. The overall complication rate was 48%, and the overall mortality rate was 2%. Average lymph nodes retrieved ranged from 7 to 36 nodes, with a mean of 15 nodes, and positive margins of resection were reported to be positive in 0.4% of patients with malignant disease. It should be noted that all these patients were highly selected and operated in expert center. The data in these series were difficult to interpret because of the heterogenicity of the pathologies and techniques used. So far, only two studies available comparing laparoscopic and open pancreaticoduodenectomy.[11,12] All these results failed to demonstrate clear advantages over open pancreaticoduodenectomy. Despite these advances and the reports of early series with the complexity of the surgery the majority of pancreatic surgeons are still not convinced of its potential benefits. In addition, due to the technical

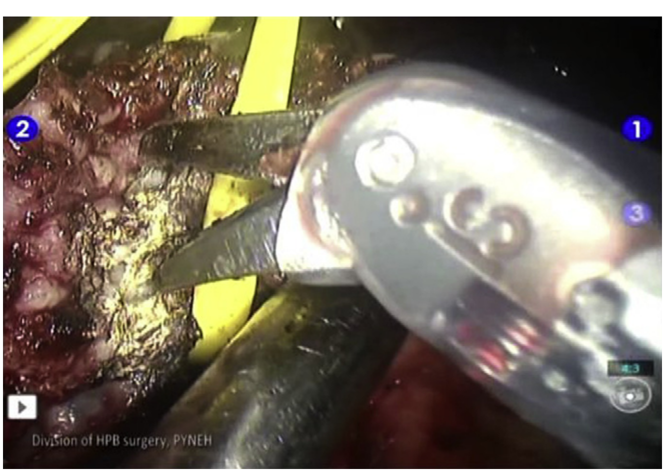

Fig. 5. Transection of pancreatic neck.

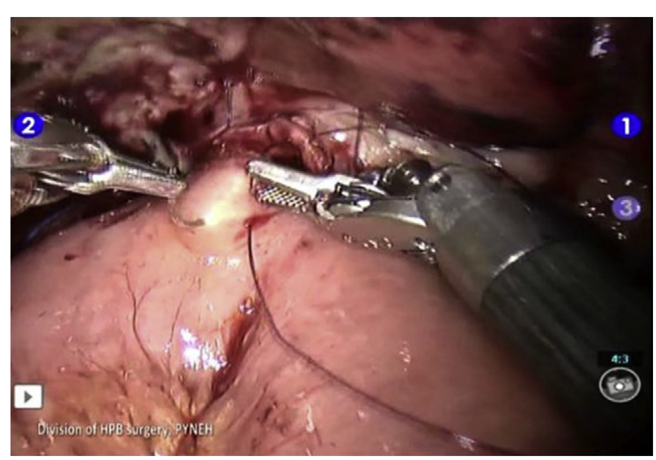

Fig. 7. Hepaticojejunostomy.

Table 1
Details of patient, operation and pathology.

Variables (*n*)	Robotic approach (*n* = 20)	Open approach (*n* = 67)	*p*-value
Age, mean ± SD	66.4 ± 11.9	62.1 ± 11.2	0.13
Gender (male/female)	12 (60%)/ 8 (40%)	38 (56.7%)/ 29 (43.3%)	0.79
ASA score			0.20
1	4 (20%)	5 (7.5%)	
2	16 (80%)	62 (92.5%)	
3	0 (0%)	0 (0%)	
Malignant pathology			0.70
Ca pancreas	7 (35%)	24 (35.8%)	
Cholangiocarcinoma	1 (5%)	10 (14.9%)	
Ca ampulla	5 (25%)	14 (20.9%)	
IPMN	1 (5%)	2 (3%)	
Duodenal GIST	1 (5%)	2 (3%)	
Neuroendocrine tumor	0 (0%)	1 (1.5%)	
Benign pathology			
Neuroendocrine tumor	0 (0%)	2 (3%)	
Ca ampulla in-situ	1 (5%)	0 (0%)	
Chronic pancreatitis	1 (5%)	2 (3%)	
IgG4 autoimmune pancreatitis	0 (0%)	1 (1.5%)	
Solid pseudopapillary neoplasm	1 (5%)	0 (0%)	
IPMN	0 (0%)	2 (3%)	
Serous cystic adenoma	1 (5%)	2 (3%)	
Villous tubular adenoma	1 (5%)	1 (1.5%)	
Adenomyomatous inflammation	0 (0%)	4 (6%)	
Tumor size (cm)	2.1 ± 0.7	2.9 ± 2.3	0.15
Whipple's operation	20 (100%)	63 (94%)	0.26
Pylorus preserving pancreatico-duodenectomy	0 (0%)	4 (6%)	
Pancratico-jejunostomy	20 (100%)	65 (97%)	0.43
Pancratico-gastrostomy	0 (0%)	2 (3%)	
Duct-to-mucosa anastomotic technique	17 (85%)	47 (70.1%)	0.18
Dunking anastomotic technique	3 (15%)	20 (29.9%)	
Mean lymph node harvested	10 ± 6	10 ± 8	0.99
R0 resection rate in malignant pathology	11 (73.3%)	34 (64.1%)	0.92

difficulties of minimally invasive pancreaticoduodenectomy, few centers have adopted this minimally invasive approach. Indeed, we also agree that there is a long learning curve for this complex procedure, although the number of cases that need to pass this learning curve is still not known. In our study, there was no significant difference in the operating time between the first 10 and second 10 patients. The possible reason is that before the robotic system installation in our unit, we have accumulated certain experience and skills in 10 hand-assisted laparoscopic pancreaticoduodenectomies. Therefore, when we adopted the technique of robotic approach, the difficulties would be less than usual.

Table 2
Intraoperative and post-operative outcome.

Variables (*n*)	Robotic approach (*n* = 20)	Open approach (*n* = 67)	*p*-value
Mean operating time (min)	491.5 ± 94	264.9 ± 63.7	0.01
Mean blood loss (ml)	247 (50–889)	774.8 (50–8000)	0.03
Open conversion	1 (5%)	\	\
Number of patients with complication	10 (50%)	33 (49.3%)	0.95
Overall complication			
Pancreatic fistula	7 (35%)	12 (17.9%)	0.11
Bile leakage	3 (15%)	4 (6%)	0.19
Post-operative hemorrhage	2 (10%)	3 (4.5%)	0.04
Intra-abdominal collection/abscess	2 (10%)	9 (13.4%)	0.69
Bowel ischemia	1 (5%)	0 (0%)	0.06
SMV thrombosis	0 (0%)	1 (1.5%)	0.58
Delayed gastric emptying	1 (5%)	8 (11.9%)	0.37
Wound infection	1 (5%)	4 (6%)	0.87
Reoperation rate	2 (10%)	3 (4.5%)	0.04
Post-operative death	0 (0%)	2 (3%)	0.43
Mean post-operative hospital stay (days)	13.7 ± 6.1	25.8 ± 23.1	0.02

Conventional laparoscopic surgery has its own limitations, including reduced freedom of movement within the abdominal cavity and 2-dimensional view of a 3-dimensional operative field. In addition, the laparoscopic instruments provide surgeons with reduced precision and poor ergonomics. These limitations translate into a long learning curve, requiring a lot of time and effort to develop and maintain such advanced laparoscopic skills. These shortcomings of laparoscopic surgery were the impetus behind the development of robotic surgery. Robotic surgery is the latest technological advance in minimally invasive surgery. Its future implementation will depend on the advantages that it can provide over conventional laparoscopy or open surgery. They increase dexterity, restore proper hand-eye coordination and an ergonomic position, and improve visualization.[13,14] Several steps of the pancreatectomy may be improved with robotic surgery, including dissection of the pancreatic gland from major vasculatures, lymph node dissection, dissection and resection of the uncinate process, and reconstruction of anastomoses. The procedure emphasizes teamwork between two experienced pancreatic surgeons and requires a four-handed technique for appropriate retraction and exposure of critical structures. However, there are also several disadvantages to these systems. First of all, robotic surgery is a new technology and its uses and efficacy have not yet been well established. Another disadvantage of these systems is their cost.

To the best of our knowledge, only three studies have been published comparing the robotic approach and the open approach for pancreaticoduodenectomy.[15–17] No randomized trial has been reported. Zhou et al. from Beijing, China showed robotic group ($n = 8$) had a significantly longer operating time (718 vs. 420 min), reduced blood loss (153 vs. 210 ml), and a shorter hospital stay (16.4 vs. 24.3 days) compared to the open group ($n = 8$).[15] Robotic group had a significantly lower complication rate (25 vs. 75%). There was no significant difference in mortality rate (0 vs. 12.5%) and R0 resection rate (100 vs. 83.3%). Buchs et al. from Chicago, US showed that robotic group ($n = 44$) had a significantly shorter operating time (444 vs. 559 min), reduced blood loss (387 vs. 827 ml) compared to the open group ($n = 39$).[16] There was no significant difference in complication (36.4 vs. 48.7%), and mortality rate (4.5 vs. 2.6%). A higher number of lymph nodes harvested (16.8 vs. 11) in robotic group. There was no significant difference in R0 resection rate (90.9 vs. 81.5%). Chalikonda et al. from Cleveland, US showed that robotic approach ($n = 30$) had a significant longer operating time (476.2 vs. 366.4 min) but decreased length of stay (9.79 vs. 13.26 days) compared to the open group ($n = 30$).[17] There was no significant difference in complication (30 vs. 43%), and mortality rate (4 vs. 0%). There was no significant difference in number of lymph nodes harvested (13.2vs. 11.76). Robotic group had a higher R0 resection rate (100 vs. 87%). Our study showed similar outcome to these studies. When compared to open approach, robotic approach was associated with a significantly longer operating time, reduced blood loss, and a shorter hospital stay. There was no significant difference in complication rate, mortality rate, R0 resection rate and number of harvested lymph nodes.

The current role of minimally invasive pancreaticoduodenectomy is unclear when compared with other advanced abdominal procedures. It is a complex abdominal operation with high morbidity, the majority of which is not attributable to the surgical wound. Pancreatic fistula/anastomotic leakage remain the single most important morbidity after pancreaticoduodenectomy and contribute to prolonged hospitalization and mortality.[3] All the reported series, including our study, showed that robotic approach failed to decrease the rate of pancreatic fistula/anastomotic leakage. In the present series, the complication rate was clearly not reduced by the robotic approach. In our study, the robotic group had a statistically non-significant higher pancreatic fistula rate and a significantly higher reoperation rate. Part of the reason might be due to the learning curve issue. With the small number of patients in the robotic group, it is still too early to draw any conclusion. Hopefully, with more experience, the complication rate will be lower. We have also analyzed the cause of difference in hospital stay in both groups in our study. The main reason was due to the prolong hospital stay in those patients with complications in the open group. In the 16 patients with pancreatic or biliary fistula in the open group, 13 patients had stay in the hospital more than 1 month time. In addition, there are also some concerns with regard to its application and the prolonged surgery time required. For example, the appropriateness of its application for oncologic resection has not been thoroughly established. Based on the current evidence, despite technical feasibility of robot-assisted laparoscopic pancreaticoduodenectomy, in the absence of obvious definitive advantages over the open approach, and in light of remaining uncertainties regarding long-term oncologic outcome, caution should be exercised in the assessment of the appropriateness of this operation for individual patient.

In conclusion, robotic-assisted laparoscopic pancreaticoduo denectomy is feasible and safe in appropriately selected patients. However, it should only be performed by surgeons experienced with traditional open pancreaticoduodenectomy and other advanced laparoscopic surgery. It is still too early to draw definitive conclusions concerning the value of robot-assisted laparoscopic pancreatico duodenectomy. Prospective randomized studies with a greater number of cases are needed to confirm its role.

Ethical approval

Not applicable.

Funding

No.

Author contribution

Lai ECH contributed to the study design, data collection, data analysis and writing. Yang GPC and Tang CN contributed to the study design, data analysis and proof read.

Conflict of interest

All the authors had no conflict of interest.

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