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ORIGINAL ARTICLE

Early experience of laparoscopic and robotic hybrid pancreaticoduodenectomy

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Abstract

Background Laparoscopic surgery and robotic surgery have their own merits and demerits. The aim of this study was to evaluate early experiences of hybrid pancreaticoduodenectomy (PD) and to identify the learning curve of robotic surgery.

Methods Sixteen patients underwent hybrid PD from August 2015 to February 2016. The outcomes were compared with those of an open PD group by the same operator during the same period. The resection time and anastomosis time were analyzed.

Results Six patients in the hybrid PD group developed complications. The postoperative hospital stay in the hybrid surgery group was significantly shorter than the open PD group (10.9 ± 3.2 vs 16.9 ± 8.8 days). The total operative time of hybrid surgery was significantly longer than that of open surgery (414.7 ± 47.0 vs 266.0 ± 51.1 minutes). In hybrid surgery, the actual operation time reduced with experience, particularly anastomosis time.

Conclusion Hybrid PD is feasible and safe. The learning curve of hybrid surgery, particularly robotic anastomosis, is relatively short.

KEYWORDS

laparoscopy, learning curve, outcome, pancreaticoduodenectomy, robotic surgical procedure

1 | INTRODUCTION

Although minimally invasive surgery (MIS) has been attempted in pancreatic surgery, laparoscopic pancreaticoduodenectomy (PD) has not been widely conducted because of the complex surgical anatomy and difficult anastomoses involved, particularly in pancreaticojejunostomy (PJ). Robotic surgery may overcome these difficulties with laparoscopic surgery, especially through the ability to perform the anastomosis using a 3D magnified view, with stable handling and precise suturing because of the enhanced degree of freedom. However, robotic surgery also has disadvantages. The instruments equipped to the robot arm are limited, and it is difficult to change the patient position or alter the camera port after docking. To overcome these disadvantages while maintaining its advantages, laparoscopic and robotic hybrid PD, combining aspects of laparoscopic surgery and robotic surgery, was attempted. The aim of this study was to analyze the early experiences of hybrid PD and to evaluate the feasibility of hybrid surgery

Hongbeom Kim and Jae Ri Kim contributed equally to this study.

2 | MATERIALS AND METHODS

2.1 | Patients

Sixteen patients who underwent laparoscopic and robotic hybrid PD at Seoul National University Hospital, Seoul, Korea, between September 2015 and February 2016 were included in this study. The results of 64 patients who underwent open PD during the same period and performed by the same surgeon were compared with those of hybrid PD. Clinical data were collected prospectively in electronic medical records. This study was approved by the Institutional Review Board, which waived the requirement for informed consent from the patients (IRB No.: 1605–088-762).

2.2 | Operation procedure

2.2.1 | Ports insertion

Six ports were placed during the surgery (Figure 1). Five ports were inserted into the lower abdomen, including four arms for the robot

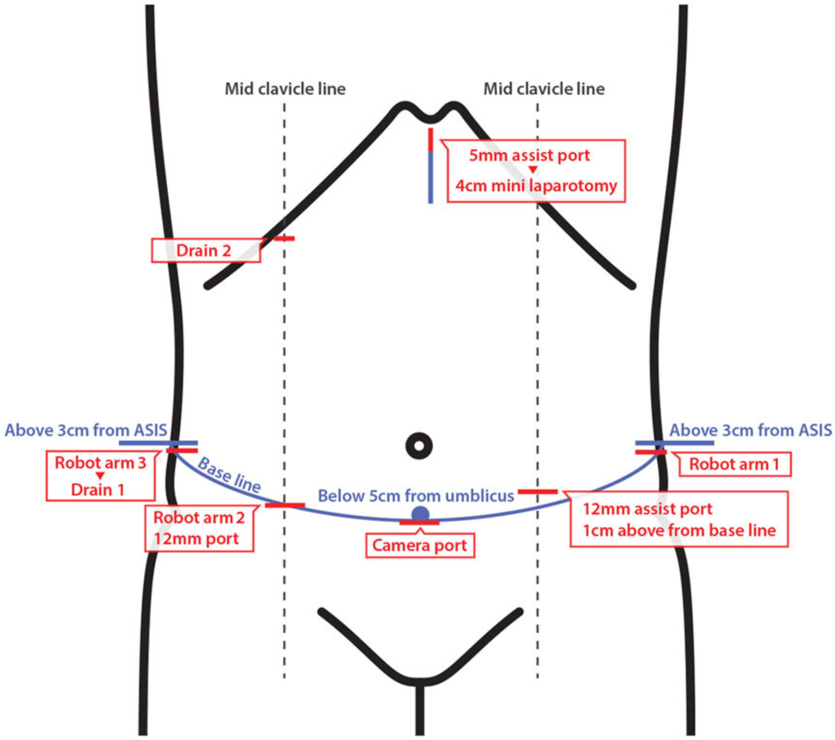

FIGURE 1 Port sites of hybrid PD

(R1, R2, R3, C) and one arm for the assistant (A). One port was inserted in the epigastric area for retraction of the liver. Of the four ports for the robot, R1/R3 are 8 mm ports located laterally to the midclavicular line, 2–3 cm above the anterior superior iliac spine (ASIS) level; R2 is a 12 mm port located on the right midclavicular line, and C (Camera port) is a 12 mm port located 2–3 cm to the right and 5 cm below the umbilicus. Both R2 and C could be used for the camera, depending on the view of the operative field. The assistant port (A) was inserted 3–4 cm below the camera port (C) on the left midclavicular line.

2.2.2 | Laparoscopic resection (Figure 2)

Resection was performed by laparoscopy. After exploration, gastrocolic ligament opening commenced. The right gastroepiploic and right gastric vessels were found and resected after ligation. The Kocher maneuver was performed to free the duodenum. After clearing the perigastric vessels and tissue around the pylorus, the duodenum was transected. Dissection of the hepatoduodenal ligament was performed. The common bile duct (CBD) was ligated with Hem-o-lock clips (Teleflex, Morrisville, NC, USA) on the distal CBD stump and with a bulldog clamp on the proximal remnant portion of the CBD.

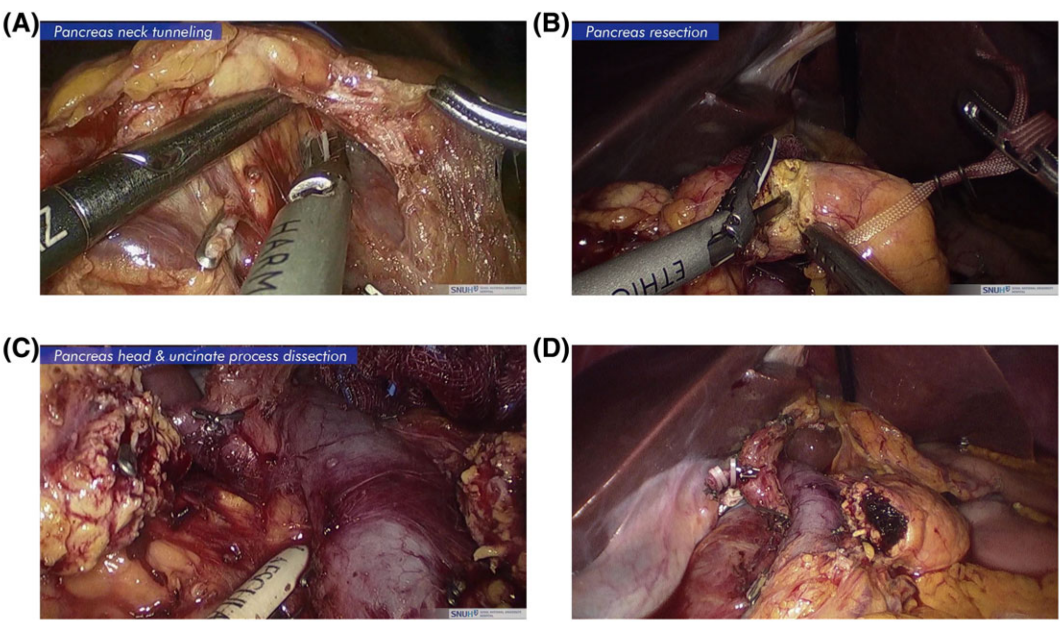

FIGURE 2 Laparoscopic resection: (A) pancreas neck tunneling; (B) pancreas resection; (C) uncinated dissection; (D) operation field after resection

Tunneling was performed beside the neck of the pancreas along the superior mesenteric vein (SMV). After dissection of the Treitz ligament, transection of the jejunum and mesenteric resection was performed. The parenchyme of the pancreas was transected with the active blade of a Harmonic Scalpel® (Ethicon Endosurgery, Cincinnati, OH, USA), and the pancreatic duct was transected with endo-scissors. Depending on the field of view, the gastroduodenal artery (GDA) could be transected after pancreatic resection or just after the dissection of the hepatoduodenal ligament. After taking the specimen from the left to the right side of the portal vein through the mesenteric window, dissection of the pancreatic head and uncinate process was performed with Caiman® (a vessel-sealing instrument), metallic clips, and the Harmonic Scalpel®. The specimen was placed in a Lapbag® (Sejong, Paju, South Korea) and removed through the 12 mm sized trocar site. Irrigation and hemostasis were performed. After placing tagging sutures on the duodenum and jejunum for duodenojejunostomy, robot docking was started for the anastomosis.

2.2.3 | Robotic anastomosis: PJ

The anastomosis was performed using a robotic platform, the da Vinci Si system (Intuitive, Sunnyvale, CA, USA). The robotic PJ procedure was the same as that of the author's open PJ method, with a 2-layer end-to-side duct to mucosa type anastomosis.[1] After identifying the correct size of internal silicon tube, a 6–0 PDS® (Ethicon, Cincinnati, OH, USA) stitch in the 9 o'clock direction (dorsal side) of the pancreatic duct was performed first because of the difficult view. A continuous suture with 4–0 Surgipro® (Covidien Medtronic, MN, USA) between the posterior side of the pancreatic parenchyme and the jejunum was performed from the upper border to the lower border (Figure 3A). An anchoring suture with 4–0 Surgipro® was placed at the inferior margin of the pancreas. During this continuous suture, the assistant holds the suture material and maintains proper tension to avoid loosening of the suture. After enterotomy with robotic cautery shears, the internal stent was inserted and a tagging suture was performed using the same 6–0 PDS® suture used in the 9 o'clock direction. Another 4-to-6 interrupted duct-to-mucosa anastomosis was performed with 6–0 PDS® (Figure 3B,C). Finally, a continuous suture with 4–0 Surgipro® on the anterior layer of the pancreatic parenchyme and jejunum was performed (Figure 3D). For clearing the field, the assistant frequently use a suction irrigator during the entire robotic procedure. Polyethylene glycolic acid mesh was wrapped around the PJ site and fibrin glue was applied.

2.2.4 | Robotic anastomosis: Hepaticojejunostomy (HJ)

Single-layer end-to-side HJ was performed 10 cm distally from the PJ site. Interrupted sutures with 5–0 Vicryl® (Ethicon, Cincinnati, OH, USA) on the posterior wall and anterior wall were performed (Figure 4). If the diameter of the bile duct is larger than 1 cm, continuous sutures can be applied more comfortably than interrupted sutures. Until the HJ is completed, the cystic duct is ligated, but the gallbladder is left attached to the liver for retraction. After HJ, the gallbladder was separated from the liver bed and removed through the Lapbag®. Docking was then released and the robotic platform separated.

2.2.5 | Specimen retrieval and extracorporeal duodenojejunostomy

A 4–5 cm small incision was made in the epigastric area, including the 5 mm trocar incision. After applying Alexis® wound protector (Applied Medical, Rancho Santa Margarita, CA) to this mini laparotomy site, the specimen was removed. Extracorporeal duodenojejunostomy was performed through the same site (Figure 5).

2.2.6 | After reconstruction

Two Jackson–Pratt drains were inserted through the R3 port site and into the right upper quadrant area. These drains were located anterior and posterior to the HJ and PJ anastomosis.

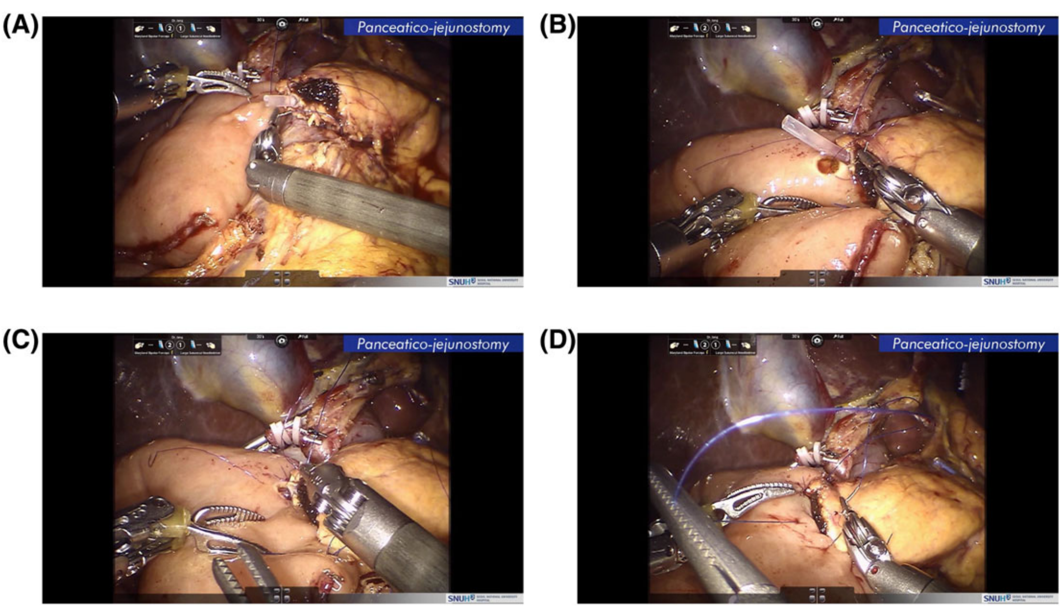

FIGURE 3 Pancreaticojejunostomy with robot: (A) continuous suture of posterior outer layer; (B) duct to mucosa suture (dorsal side); (C) duct to mucosa suture (ventral side) (D) continuous suture of anterior outer layer

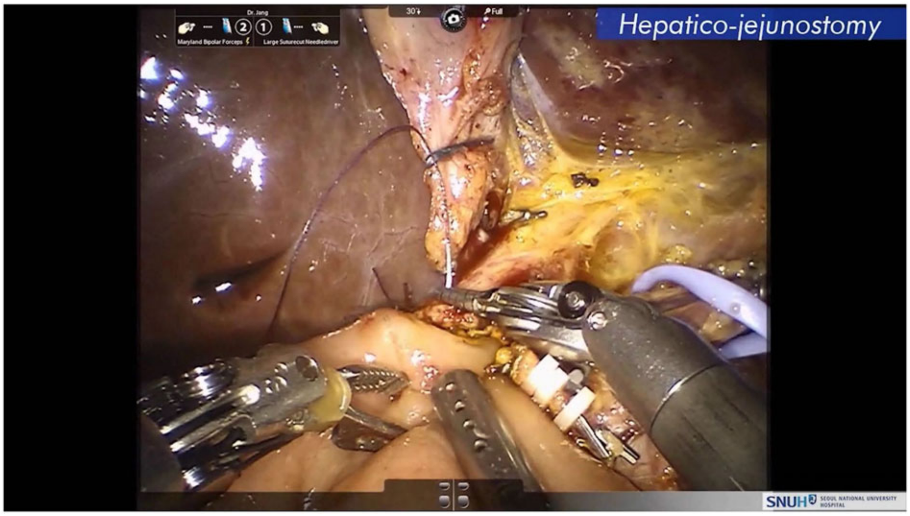

FIGURE 4 Hepaticojejunostomy with robot

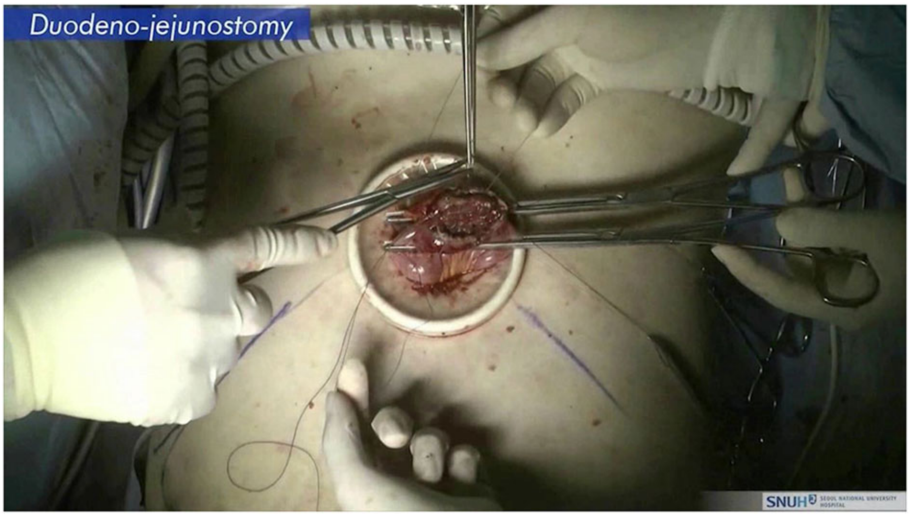

FIGURE 5 Extracorporeal duodenojejunostomy

2.3 | Operation time

In the analysis between open and hybrid surgery, total operation time was compared. The learning curve of hybrid surgery is illustrated by actual operation time, being the sum of resection time and anastomosis time, excluding preparation, setting, and resting time of the operator and assistant.

2.4 | Complications

The Clavien-Dindo classification was used for grading postoperative complications. Postoperative surgical complications were considered to have occurred in cases that were classified above grade III within 30 days.

2.5 | Statistical analysis

All statistical analyses were performed with SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Nominal data were compared with the chi-square test and continuous data with Student's t-test. *P* values of less than 0.05 were considered statistically significant.

3 | RESULTS

3.1 | Demographics

The characteristics of the two groups are shown in Table 1. The mean age and mean body mass index (BMI) did not show any differences between the hybrid and open PD groups. In hybrid PD, the number of patients with benign and malignant disease were the same (n = 8 in both). Intraductal papillary mucinous neoplasm (IPMN) was the most common benign disease (n = 4, 25%); other benign diseases were ampulla of Vater (AoV) adenoma (n = 2), grade 1 neuroendocrine tumor (n = 1), and low risk gastro-intestinal stromal tumor (n = 1). Three patients from five were early cancer derived from IPMN and one was early pancreatic ductal adenocarcinoma without lymph node metastasis. In contrast

TABLE 1 Comparison of hybrid and open PD group

Factors	Hybrid (n = 16)	Open (n = 64)	*P-value*
Age (mean ± SD, years)	63.1 ± 9.8	65.9 ± 8.9	0.354
Sex (male: female)	6: 10	42: 24	0.031
BMI	21.8 ± 2.8	23.5 ± 2.8	0.077
Disease type Benign	8 (50%)	4 (6.2%)	<0.001
Malignancy	8 (50%)	60 (93.7%)	
Diagnosis			
IPMN	4 (25.0%)	4 (6.2%)	
Pancreatic cancer	5 (31.2%)	22 (34.3%)	
CBD cancer	0 (0%)	25 (39.0%)	
AoV cancer	2 (12.5%)	10 (15.6%)	
Duodenal cancer	1 (6.2%)	3 (4.6%)	
Others	4 (25.0%)	0 (0%)	
Total operation time (mean ± SD, minutes)	414.7 ± 47.1	266.1 ± 51.1	<0.001
EBL (mean. ± SD, ml)	323.6 ± 189.3	411 ± 244.1	0.263
Complications	6 (37.5%)	13 (20.3%)	0.186
Clinical relevant POPF	3 (18.7%)	8 (12.5%)	
Wound	1 (6.2%)	3 (4.6%)	
Bleeding	1(6.2%)	3 (4.6%)	
DGE	1(6.2%)	4 (6.2%)	
Fluid collection	0 (0%)	1 (1.5%)	
Hospital stay (mean ± SD, days)	10.9 ± 3.2	16.9 ± 8.8	0.027

SD: standard deviation, AoV: ampulla of Vater, CBD: common bile duct, IPMN: intraductal papillary mucinous neoplasm EBL: estimated blood loss, POPF: post-operative pancreatic fistula, DGE: delayed gastric emptying

to the hybrid surgery, diseases in conventional open PD were mostly malignancies (*n* = 60, 93.7%)

3.2 | Clinical outcomes

The total operation time was significantly longer, and the postoperative hospital stay significantly shorter in the hybrid PD group than in the open PD group (total operation time, 414.7 ± 47.1 min vs 266.1 ± 51.1 min, $P < 0.001$; postoperative stay, 10.9 ± 3.21 days vs 16.98 ± 8.80 days, $P = 0.027$).

Six patients (37.5%) in the hybrid PD group had postoperative complications. Three patients had postoperative pancreatic fistula, one had a wound infection, one had delayed gastric emptying, and one patient had postoperative mesenteric bleeding and underwent reoperation for bleeding control. Thirteen patients (20.3%) had various complications in the open PD group. The complication rate was not significantly different between the two groups ($P = 0.186$).

Of 16 hybrid cases, eight were malignant diseases and in all eight cases the resection margin was negative. The median value of retrieved lymph node was 28 (range 18–32) and there was no difference between the open group and hybrid group. Three patients had adjuvant treatment performed within 5 weeks.

3.3 | Change of operation time

Difficulties occurred in some cases. Cases 3 and 14 had long resection times due to severe adhesion because of pancreatitis and adjacent inflammation, and poor vision, respectively. In contrast, a case of difficult HJ because of a small common hepatic duct (case 8) and a case of difficult PJ because of a 1 mm diameter pancreatic duct (case 12) had long anastomosis times. Despite these difficult cases, the actual operation time shortened with experience, particularly the anastomosis time. Actual operation time was maintained at less than 350 min after the 6th case. Anastomosis time also deceased and was maintained consistently after the 8th case (Figure 6).

4 | DISCUSSION

MIS is widely performed in general surgery fields. In pancreatic surgery, the most popular type of MIS is laparoscopic distal pancreatectomy. On a systematic review, laparoscopic distal pancreatectomy demonstrated its merits, namely reduced blood loss,

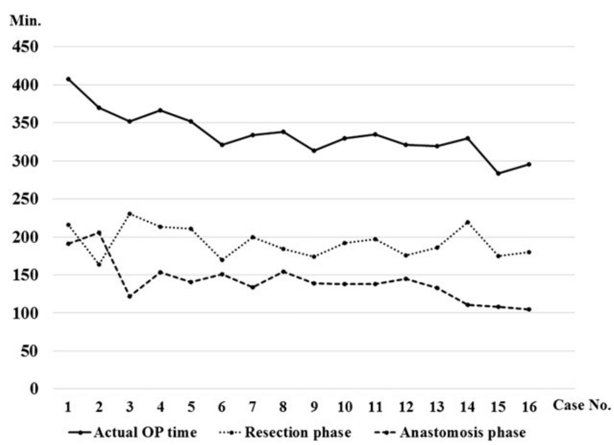

FIGURE 6 Trends in operation time

shorter hospital stay, and early oral intake compared with open surgery. Laparoscopic surgery is an effective and safe surgery in distal pancreatectomy.[2] However, laparoscopic PD (LPD) still occupies a small proportion of PD. Gagner et al. reported the first LPD in 1994,[3] however, LPD is still not accepted as a standard alternative to open PD. There are several obstacles to the adoption of LPD; however, the most challenging factor is performing the anastomoses, particularly PJ anastomosis, because of the small size of the pancreatic duct. A large amount of experience is required to perform it safely.

Robotic surgery provides 3-dimensional magnified views, and enables elaborate movements with an articulated arm. These advantages are maximized in fixed small surgical fields that are difficult to approach with straight instruments, such as the prostate, thyroid, and rectum.[4–6] With these advantages, in low rectal surgery, robotic surgery can be used to dissect pelvic lateral lymph nodes and provide better functional outcomes than laparoscopic surgery.[7] In PD, these advantages of the robot, particularly of the articulated arm, make it feasible to perform secure duct-to-mucosa anastomoses. Some studies have recommended that LPD should not be performed routinely because LPD is associated with post-operative pancreatic fistula (POPF), resulting in high morbidity and mortality.[8] A secure PJ anastomosis is very important in PD, and robotic PD (RPD) is a suitable operative type for MIS-PD. Many reports have suggested the safety and efficiency of RPD. The POPF rate of RPD is 0–25%, the reoperation rate is 0–10%, and the conversion rate to open surgery is 0–37.5%. Various outcomes of RPD have been reported. The mortality and morbidity rates are comparable with those of open surgery with shorter hospital stays.[9–15] Therefore, the cases of RPD being performed have increased, with acceptable outcomes compared with that of LPD.[10,16] There also seems to be a short learning curve, although experiences are still early.

Robotic surgery is effective in a small fixed field with magnified view, although it has its limitations in abdominal surgery requiring a wide field of view. Recent models, including the da Vinci Xi system (Intuitive, Sunnyvale, CA, USA), have attempted to overcome this disadvantage. Another disadvantage is that the instruments, especially energy devices, fitted to the robot arm are limited. The area of PD is wide and vessels of various diameters are involved; therefore, effective instruments suitable for each procedure are needed. The time interval to allow instrument changes is longer in robotic surgery than in laparoscopic surgery, reducing the ability for a prompt response to emergencies such as bleeding. Laparoscopic surgery is more effective than robotic surgery in complex surgeries, which require various instruments and instrument changes, and in wide surgical fields, involving more than two quadrants of the abdomen.

There are several types of MIS in PD: pure laparoscopic, pure robotic, hand assisted, and laparoscopic–robotic hybrid. The choice between laparoscopic and robotic hybrid PD is made on the basis of the merits and demerits of each technique (Table 2). In laparoscopic surgery, movements by the operator are quicker with frequent instrument changes. This enables a prompt response to intraoperative difficulties encountered, such as bleeding. The ranges of motion for the operator and assistant are also wider. As the PD surgical field of the resection phase is wide and the dissection area is located deep in the abdomen, the ability to change position is helpful to enable a clear operative field. However, in the robotic system, the patient's position is fixed after docking, except in the most recent model robot, the da Vinci Xi system (Intuitive, Sunnyvale, CA, USA). In addition, in laparoscopic surgery, the camera can be inserted into different ports easily to provide another view from a different angle. When performing dissection around the superior mesenteric artery area, the camera was inserted through the R2 port, and not through the C port. These factors make laparoscopic surgery more suitable for the resection phase in PD. On the other hand, a fixed field and fine movement are necessary in the anastomosis phase, so robotic surgery is more suitable for anastomosis. A hybrid surgery using laparoscopic and robotic surgery is a useful technique to perform MIS-PD, and helps to overcome the weak points of each surgery.

TABLE 2 Merits and demerits of laparoscopic and robotic procedures

	Laparoscopic procedure		Robotic procedure
Range of motion		>>	
Operator	Wide		Limited
Assistant	Wide		Very limited
Quick movement	Easy	>	Difficult
Available instruments	Many	>	Less
Vision	2D	<<	3D magnified
Fine dissection	Difficult	<	Easy
Suture	Very difficult	<<<	Precise, fast

A secure anastomosis could also be feasible in pure laparoscopic surgery. The overall POPF rates in LPD and RPD were comparable (19.5% and 21.5%, respectively, P = 0.467) in a recent systemic review.[17] However, this requires a large amount of experience and has a steep learning curve because of the many limitations in LPD. It is difficult to define the number of cases required to overcome the LPD learning curve, although more than 40 or 50 cases may be required.[18] The learning curve of RPD is relatively shorter than that of LPD.[10,11] Broone et al. [12] reported that the learning curve of RPD was overcome in 20 cases for blood loss and conversion rate and in 40 cases for fistula rate. Hybrid surgery required additional time for robot docking and separation as well as for instrument changes for each platform. The operator and assistant also needed rest because of the long operation time. To identify the learning curve, therefore, actual operation time was defined as the sum of pure resection time and pure anastomosis time, excluding preparation time and resting time. In our early experience, actual operation time was between 5 and 6 h after the 6th case, remaining relatively consistent, and anastomosis time showed a similar trend. The number of cases to overcome the learning curve is small, showing another advantage of RPD. This trend may be due to the lower ergonomic barrier in robotic surgery.[19] Another cause of short learning curve is the training system of the robot. Virtual simulators and dual console systems can provide high quality education to trainees,[20,21] and can contribute to a short learning curve.

PD is a complex surgery requiring a long operation time. Surgeon fatigue is also an important factor that influences surgical outcome. In lengthy laparoscopic surgery, muscle strain on the shoulder, neck, and wrist occurs. Likewise, lengthy robotic surgery could lead to eye fatigue and neck strain. Robot-assisted laparoscopy surgery is less physically stressful, avoids lengthy fixation of position, and provides an ergonomic position.[22] However, a clear relationship between surgeon fatigue and surgical outcome does not exist.[23]

Indications for MIS-PD are not yet established. In this study, most patients had benign or borderline disease on pre-operative diagnosis. On the final diagnosis, half of the patients had malignant disease, including five cases of pancreatic cancer. Three patients out of five had early cancer derived from IPMN and one had early pancreatic ductal adenocarcinoma without lymph node metastasis. However, one patient had pancreatic ductal adenocarcinoma with pathologic stage T3 N1. The feasibility of MIS on aspects of long-term outcome has been reported in other abdominal cancer surgeries.[24,25] Likewise, laparoscopic distal pancreatectomy showed acceptable long-term outcomes compared with open distal pancreatectomy in pancreatic tail cancer.[26,27] In line with the principle of resection of malignant disease, MIS-PD would show results similar to those of open surgery, although long-term results are required to analyze this further.

In conclusion, laparoscopic and robotic hybrid PD is feasible and safe, with similar complication rates and shorter hospital stays compared with open PD. The learning curve of robotic anastomosis is relatively short, particularly for anastomosis time. With accumulation of experience, surgical indications for hybrid PD could be expanded because of the many merits of minimally invasive surgery.

DISCLOSURES

The author has no conflicts of interest or financial ties to disclose.

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