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Internal Hernia Following Robotic Assisted Pancreaticoduodenectomy

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Data Collection B
Statistical Analysis C
Data Interpretation D
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Background: Robotic assisted pancreaticoduodenectomy (RPD) is reported to be safe and feasible. Internal hernia (IH) after RPD is a serious but rarely reported complication.

Material/Methods: We retrospectively reviewed data of 231 patients who underwent RPD from October 2010 to December 2016. The incidence, symptoms, time of presentation, and outcome were investigated.

Results: Five patients (2.6%) were diagnosed with IH. Significant correlation ($P<0.001$) between IH and transverse mesocolon defect was confirmed. In patients without defect closure, the incidence of IH was 62.5%, while patients who received defect closure experienced no IH. The median time between initial surgery and occurrence of IH was 76 days. The main symptoms were abdominal pain, nausea, and vomiting. All patients received abdominal computed tomography (CT) and were suspected to have IH according to imaging and symptoms. All patients underwent reoperation (2 laparoscopic and 3 open surgery). The median length of hospital stay was 13 days. No patient experienced a relapse after treatment.

Conclusions: Abdominal pain, nausea, and vomiting were common symptoms in our study patients who underwent RPD. IH should be suspected if there is a positive finding on CT. Timely reoperation is necessary because IH may cause intestinal ischemia. Meticulous closure of the mesenteric defect is vital to avoid IH.

MeSH Keywords: Hernia, Abdominal • Pancreaticoduodenectomy • Postoperative Complications • Robotics

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Background

Pancreaticoduodenectomy is one of the most complex pancreatic operations requiring not only demanding resection but also challenging reconstruction. Minimally invasive pancreaticoduodenectomy (MIPD) was first reported by Gagner and Pomp in 1994 [1], but the development of MIPD has been slow because it is more challenging than open surgery. Due to improvements in surgical instruments and minimally invasive surgical skills, MIPD, especially robotic assisted pancreaticoduodenectomy (RPD) has been performed with increasing frequency in recent years [2–6]. The feasibility and safety of RPD has been demonstrated by several centers [3,7–15].

However, few studies have reported internal hernia (IH) following the procedure. IH is defined as a protrusion of an abdominal organ, most commonly the small bowel, through a normal or abnormal peritoneal or mesenteric aperture [16]. IH can be either acquired through a surgical procedure or related to constitutional conditions or congenital peritoneal defects [17]. The symptoms of IH were usually nonspecific. Hence, the diagnosis of IH still remains a challenge for surgeons [18]. IH is a relatively well-studied complication in gastric and colorectal surgery [19–23]. Few studies have ever reported IH in pancreatic surgery [24], especially minimally invasively pancreatic surgery, and there have been no studies reporting IH after RPD. Owing to the high mortality associated with IH, understanding the cause, incidence, and clinical course of IH after RPD is necessary.

We retrospectively studied the clinical features and management of IH following RPD to understand the clinical manifestations of the complication. In this study, we compared the surgical procedure between patients with and without IH and studied the difference between open pancreaticoduodenectomy and RPD to determine the cause of IH in RPD and find solutions for avoiding IH.

Material and Methods

Patients

A total of 231 patients who underwent RPD from October 2010 to December 2016 were included in the study. We excluded 31 cases with no video data for analysis, and 8 cases were excluded due to conversion to open surgery. Therefore, 192 cases with available video record were studied. The diagram of patients included in the study is shown in Figure 1. All patients were followed for at least 1 year.

Patients were divided into 2 groups according to whether transverse mesocolon defect happened during their procedure.

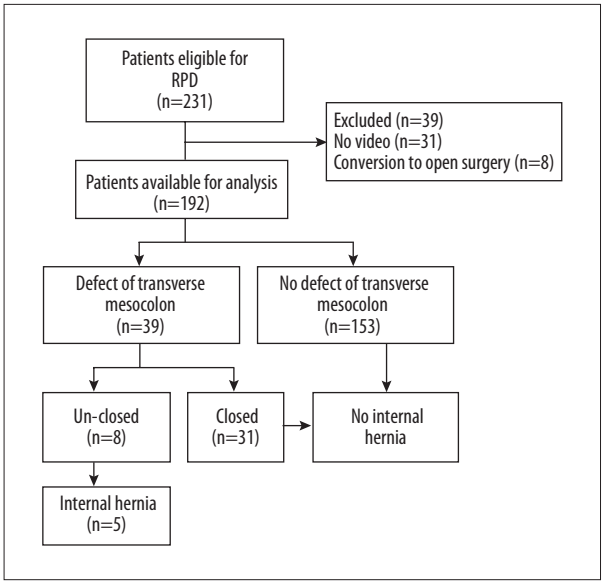

Figure 1. The diagram of patients included in the study.

Patients with symptomatic small bowel obstruction were selected and clinical characteristics were collected. For patients who were diagnosed with IH, the management, time of symptom presentation, and length of hospital stay were analyzed.

Operation procedure

The RPDs were performed using the da Vinci Surgical System Model S and Si. (Intuitive Surgical, Inc, Sunnyvale, CA, USA). The RPDs were performed according to our reported modified approach [11]. The gastrocolic ligament was dissected to expose the pancreas, then the pancreas was dissected along the inferior margin to expose the superior mesenteric vessels (SMVs). The SMVs were dissected to create a tunnel behind pancreas, and an extended Kocher maneuver was performed to mobilize the transverse duodenum and dissect the duodenojejunal flexure starting from the right margin of the ligament of Treitz beneath the superior mesenteric vessels. The jejunal loop was retracted into the right upper quadrant below the mesenteric vessels and transected at the right margin of the superior mesenteric vessels above the transverse mesocolon. After the dissection of the hepatic hilum, the gastroduodenal artery was dissected and ligated to expose the PV. The pancreatic neck was dissected to locate the pancreatic duct. The root of the SMVs was dissected from cephalically toward caudally, and the stomach was transected after the nasogastric tube was withdrawn. The jejunal loop was retracted toward the right side beneath the SMVs and positioned in the right upper quadrant for reconstruction. A 2-layered end-to-side, duct-to-mucosa pancreaticojejunostomy was performed in all patients as routine practice. The stumps of the pancreatic duct were sutured using 6-0 Prolene, and a 5F or 8F pediatric Silastic feeding tube was placed to stent the pancreatic

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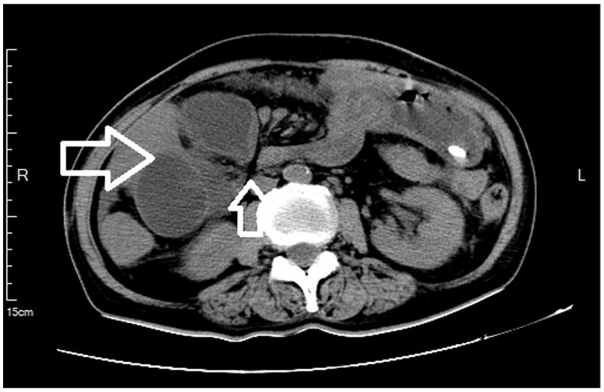

Figure 2. Computed tomography image of an internal hernia case. The left arrow shows the expanded intestine. The smaller arrow shows the hernia ring

duct. The stump of the pancreatic parenchyma was anastomosed with the seromuscular layer of the jejunum using 3-0 Prolene sutures in a horizontal mattress manner. A single-layer hepaticojejunostomy was fashioned as an end-to-side anastomosis using 5-0 Prolene sutures in a running technique for a duct >5 mm in diameter or in an interrupted technique for a duct ≤5 mm. An antecolic, 2-layered gastrojejunostomy was performed to reconstruct the gastrointestinal tract continuity. Two peritoneal drains were positioned posterior to the biliary anastomosis and inferior to the pancreatic anastomosis.

Diagnosis of IH

The study patients presented with varied symptoms including intermittent abdominal pain or distention and nausea or vomiting. Radiography and abdominal CT scan were conducted when IH was suspected. The diagnosis of IH was suggested by symptoms together with CT imaging (Figure 2).

Statistical analysis

The chi-square test was used to compare the incidence of hernia between different groups. Statistical significance was accepted at $P<0.05$, and all tests were 2-sided. Analyses were performed using the Statistical Software Package for the Social Sciences (SPSS version 22.0 for Windows, SPSS Inc., Chicago, IL, USA).

Results

Cohort characteristics

Among 192 RPD cases from October 2010 to December 2016, 5 cases (2.6%) were diagnosed with IH. Three patients were female and 2 were male. The mean age was 41.6 years (range, 19–59 years), the mean BMI was 20.80 kg/m^2 (range, 17.82–23.79 kg/m^2), and the mean operation time was 372 minutes (210–450 minutes). The mean estimated blood loss was 320 mL. The postoperative pathology showed 2 serous cystadenomas, 1 solid pseudopapillary tumor, 1 intraductal papillary mucinous neoplasm, and 1 ductal adenocarcinoma ($T_2N_0M_0$).

Correlation between IH and transverse mesocolon defect

From our retrospective study, we found that all cases of IH happened in patients with transverse mesocolon defect. We then compared the incidence of IH between patients who received defect closure to those who did not. Results showed that the incidence of IH in patients without closure was 62.5% (5/8) while patients who received defect closure did not experienced IH (0/31). The incidence was significantly higher ($P<0.001$) in the group with no closure. The results are shown in Table 1. Clinical data including gender, age, BMI, time of operation, and estimated blood loss were compared between 3 patients who didn't experience IH and 5 cases with IH, and there was no significant difference. Detailed data are shown in Table 2.

Clinical manifestation of IH

Common clinical manifestations of IH were abdominal distention, abdominal pain, and nausea or vomiting. The most common symptom was abdominal pain and distention (100%), followed by nausea or vomiting (60%). The mean time of presentation of symptom was 76 days (range, 41–160 days). Two patients had a fever over 38.5°C. Four patients met the diagnosis criteria of system inflammatory response syndrome (SIRS). The clinical manifestations are summarized in Table 3.

Management and outcome

Emergency surgery was conducted in 5 patients, 2 received laparoscopic surgery and 3 received open surgery. All 5 patients were confirmed to have IH during surgical exploration. Abdominal exploration revealed strangulated jejunal loop caused by herniation through the mesenteric opening

Table 1. IH incidences between groups divided by transverse mesocolon closure.

Group	Closed N=31	Un-closed N=8	P value
Internal Hernia, cases (%)	0 (0%)	5 (62.5%)	0.000097

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Table 2. Clinical characteristics of patients with transverse mesocolon defect without closure.

	Patients with IH (n=5)	Patients without IH (n=3)	*P* value
Gender (No.)			
Male	2	1	1.00
Female	3	2	
Age (y. o.), average ±SD	41.6±15.1	36.0±27.5	0.769
BMI (kg/m^2), average ±SD	20.8±2.2	21.3±4.8	0.868
OT (min), average ±SD	372.0±103.1	250.0±45.8	0.063
EBL (ml), average ±SD	320.0±130.4	183.3±76.4	0.111

IH – internal hernia; y. o. – year old; SD – standard deviation; BMI – body mass index; OT – operation time; min – minutes; EBL – estimated blood loss; ml – milliliter.

Table 3. The clinical manifestation and management of patients with IH.

	Time to presentation (day)	Abdominal pain/ distention	Nausea/ vomiting	Fever*	SIRS	WBC (×10^9/L)	NEU (%)	Management	L/O	LOS (day)
1	160	Y	N	Y	Y	2.79	85.6	Hernia reduction	O	13
2	41	Y	Y	N	Y	5.41	97.3	Hernia reduction	L	11
3	54	Y	Y	Y	Y	2.64	92.4	Hernia reduction	L	14
4	81	Y	Y	N	Y	3.60	78.6	Hernia reduction	O	17
5	44	Y	N	N	N	7.91	59.1	Hernia reduction	O	10

Y – yes; N – no; SIRS – system inflammatory response syndrome; WBC – white blood cell; NEU – neutrophil; L/O – laparoscopic/open surgery; LOS – length of hospital-stay; * Fever: T >38.5°C.

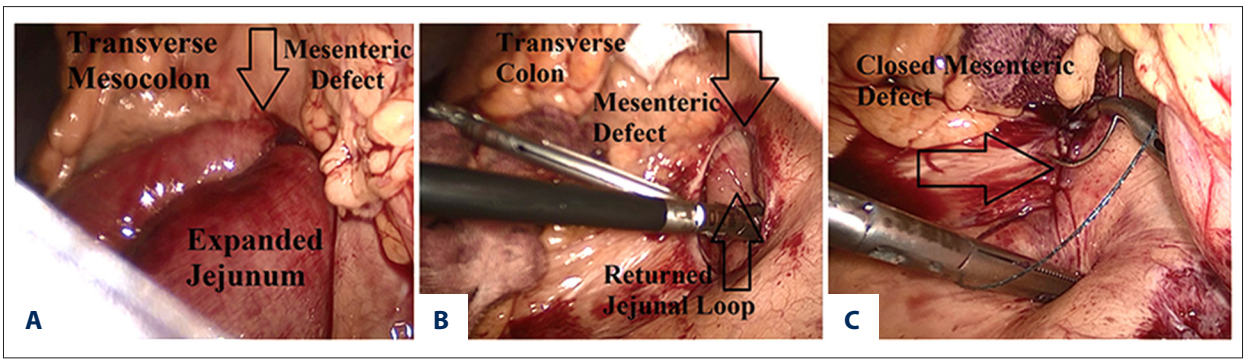

Figure 3. Laparoscopic exploration of internal hernia case. (**A**) Expanded jejunal loop caused by herniation through the mesenteric defect. (**B**) The jejunal loop was returned back through the defect of transverse mesocolon. (**C**) The mesenteric defect was closed by 3-0 V-Loc after the returning of herniation.

(Figure 3A). During surgery, the entire jejunal loop was returned without ischemic damage. No bowel resection was conducted. The mesenteric opening was closed by 3-0 V-Loc in laparoscopic surgery or 3-0 Vicryl in open surgery after the returning of the hernia. (Figure 3B, 3C). The mean length of hospital stays among patients who underwent surgical intervention was 13 days (range, 10–17 days) (Table 3). No patient experienced relapse after their treatment.

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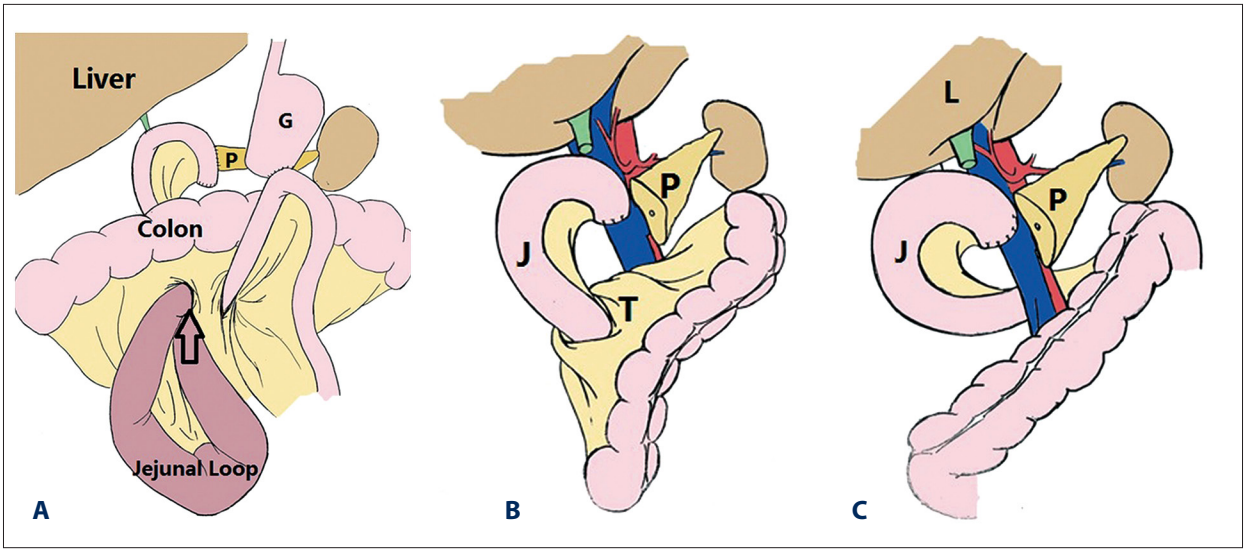

Figure 4. Schematic diagrams. (**A**) The mesenteric defect left in first operation has induced parts of the small bowels to slide into the mesenteric opening. (**B**) In open surgery, the jejunal loop is brought through the right side of the transverse mesocolon before hepaticojejunostomy and pancreatojejunostomy. (**C**) In robotic assisted pancreaticoduodenectomy, the jejunal loop is retracted from the hole, where the Treitz ligament was located, to the right upper quadrant. P – pancreas; G – gastric area; J – jejunal loop; T – transverse mesocolon; L – liver.

Discussion

RPD is a procedure for the treatment of lesions located in the head of the pancreas. RPD has been shown to be safe and feasible in recent years. There is no significant difference in terms of complication, mortality, and morbidity rates between RPD and open surgery [8–12,25–27]. The postoperative complications usually reported are pancreatic fistula, bile leakage, delayed gastric emptying, and postoperative bleeding [3]. To the best of our knowledge, few studies have reported IH following RPD. This study is a case series reporting on this rare complication.

Our study results showed that the incidence of IH was 2.6% (5 out of 192 cases). The main finding of this study was that the defect of transverse mesocolon was the cause of IH following RPD. The mesenteric defect induced parts of the small bowels to slide into the mesenteric opening (Figure 4A) to cause the hernia. Another notable observation was made: patients who received mesenteric defect repair did not develop IH. Although this conclusion seems obvious, it took us years to reach this conclusion. We suggest 2 explanations: first, the overall incidence of IH is very low; and second, in open pancreaticoduodenectomy, the mesenteric defect brings the jejunal loop to the right upper quadrant where it is easily overlooked.

It is important to note the difference between the procedure of robotic and open pancreaticoduodenectomy. In open surgery, the transverse colon and its mesentery can be elevated cephalad, the entire small bowel is eviscerated to facilitate exposure and dissection of the distal duodenum proximal to the ligament of Treitz. The jejunum is divided about 10 cm past the ligament of Treitz at a point that will provide sufficient mobility of the distal jejunum to allow one to reach easily to the right upper quadrant for the biliary and pancreatic anastomosis [28]. The end of the jejunum is brought through the right side of the transverse mesocolon before the anastomosis is made. And the jejunal loop is fixed to the transverse mesocolon after completion of the hepaticojejunostomy and pancreatojejunostomy (Figure 4B). In robotic surgery, the third and fourth portions of the duodenum are dissected after the Kocher maneuver is made. The jejunum is transected by an endo-stapler 10 cm distal to the ligament of Treitz. Then the distal jejunum is retracted to the right upper quadrant above the transverse mesocolon (Figure 4C). The jejunum is pulled up from the site where the ligament of Treitz was once located. During dissection of the hepatic flexure of the colon and the third and fourth portions of the duodenum, a mesenteric defect may be made inadvertently (Figure 5A, 5B). The opening may cause a hernia of the intestine.

Small bowel ischemia or even necrosis may happen if the patient does not get proper treatment in time. But early diagnosis of IH can sometimes be difficult. Symptoms and laboratory findings are usually nonspecific. The role of computed tomography (CT) in the evaluation of IH is critical. Hongo et al. [29] demonstrated that the key features for CT diagnosis of IH are related to previous surgical procedures. Understanding the imaging appearance on CT can enable us to diagnose IH before reoperation. In our experience, a review of the right side

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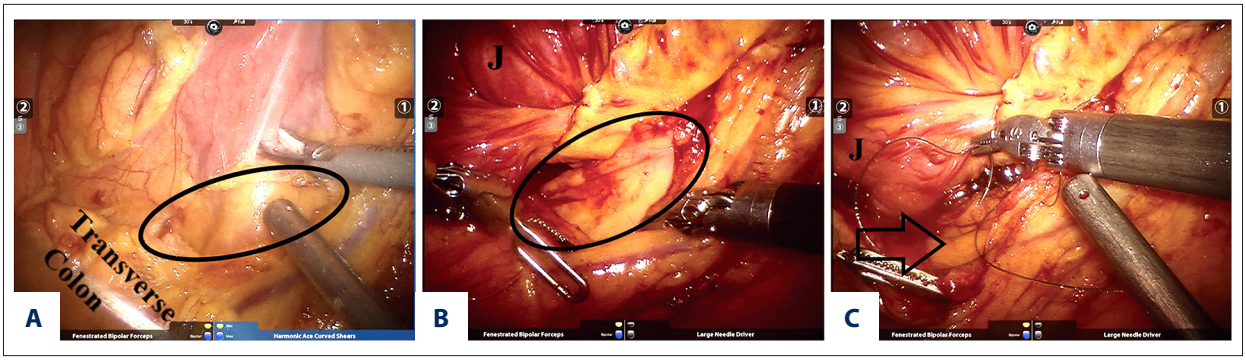

Figure 5. Mesenteric defect and closure during robotic assisted pancreaticoduodenectomy. (**A**, **B**) Mesenteric defect. (**C**) Closure of the mesenteric defect with suture. D – duodenum; J – jejunum.

of the transverse mesocolon before anastomosis is necessary. Among all 192 cases, 39 patients had mesenteric defect during RPD; the incidence of defect was 20.3%. More importantly, in only 19 cases (48.7%), were the defects seen during the dissection of the hepatic flexure of the colon and the third and fourth portions of the duodenum. In other cases, the defect was found after the specimen was removed, by a careful check. If the defect was found, it was closed with 3-0 Prolene or V-Loc (Figure 5C). No new incidence of IH occurred during RPD in the 104 cases at our center from January to September 2017.

Conclusions

IH caused by a defect of the transverse mesocolon is rare in RPD. However, closed-loop obstructions caused by herniation can be fatal and bowel resection can be avoided if IH is recognized and managed in time. Our single center retrospective study demonstrated that IH following RPD was caused by a mesenteric defect and can be prevented by meticulous closure during surgery. Although closure is only a tiny part of the whole RPD, careful attention must be paid in future operations.

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Conflict of Interest

None.

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