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Robotic pancreatoduodenectomy - how I do it: tips, tricks and pitfalls to standardize the technique to reduce postoperative morbidity and mortality

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Abstract

Pancreatoduodenectomy (PD) is increasingly performed laparoscopically (LPD) and robotically (RPD) with the benefits of minimally invasive surgery and equivalent oncological outcomes compared with conventional open PD (OPD). When LPD and RPD are compared, RPD offers better precision with 3D vision and advanced instrumentation. Although the learning curve for RPD is long with a longer operating time compared with OPD, this can be reduced to a duration similar to that for OPD through standardization of techniques and case numbers. Perioperative outcomes such as length of stay, blood loss, and transfusion requirement are significantly improved compared to OPD and fewer cases require conversion to open than LPD. In this article, we describe our approach to RPD through standardizing PD techniques along with tips and tricks for the benefit of surgeons interested in learning robotic pancreatic surgery.

Keywords: Whipple's, PD-pancreatoduodenectomy, Robotic Whipple's, OPD-open pancreatoduodenectomy, LPD-laparoscopic pancreatoduodenectomy, RPD-robotic pancreatoduodenectomy, pancreatic resection, pancreatic cancer

INTRODUCTION

The past three decades have witnessed the rapid emergence of minimally invasive surgery which has led to a total re-evaluation of conventional surgical approaches across all specialties. In hepato-pancreato-biliary (HPB) surgery, there has been a slower drive to widely embrace laparoscopic techniques, particularly for the long and technically difficult pancreatoduodenectomy (PD) operation. This operation involves precise dissection and small-caliber lumen anastomoses. Barriers to establishing laparoscopic practice, including operator discomfort and fatigue, long and steep learning curves during training, limited instrument motion, and physiological tremors which are amplified through the length of the instruments, have limited the use of these techniques in complex cases and prevented their widespread adoption in the HPB specialty. Indeed, the LEOPARD-2 trial (minimally invasive versus open pancreatoduodenectomy) comparing laparoscopic (LPD) and open PD (OPD) has recently terminated unexpectedly due to an increased 90-day complication-related mortality in the laparoscopic group [LPD 5/50 (10%) *vs.* OPD (1/49 (2%)][1]. These inherent challenges led to robotic solutions. The Da Vinci robotic system (Intuitive Surgical Inc., Mountain View, CA) gained FDA approval in 2000[2]. The major advantage of robotic surgery over the normal laparoscopic approach is that it offers a three-dimensional visual field with depth perception[2]. Furthermore, the instrumentations provide the "endo-wristed" natural seven-degree movement mimicking open surgery. By doing so, it enhances dexterity and performance to carry out difficult tasks precisely in the pelvis and deep structures for dissection and suturing that are often deemed impossible laparoscopically. Having been well-established in urology, robotic surgery is rapidly gaining momentum in other surgical specialties[3-7].

In 2003, the first successful RPD was performed by Giulianotti, demonstrating the advantages of a robotic approach to complex abdominal surgery by maximizing the benefits of minimally invasive surgery while circumventing the problems related to laparoscopic surgery[8,9]. Since then, there has been an increasing number of publications worldwide on RPD confirming the feasibility and safety of robotic pancreatic surgery with a low conversion rate to open surgery (0%-18.3%)[8,10]. These results suggest that RPD is superior to the laparoscopic approach in terms of the learning curve, supported by the results of our own randomized controlled trial on laparoscopic vs robotic training showing a much shorter learning curve to acquire surgical skills in the robotic training group compared with the laparoscopic group[11]. Furthermore, the short-term outcomes of RPD are better than the standard open technique with regards to the length of stay, blood loss and transfusion rate, and equivalent to lymph node yield and R0 resection rate[8,9,11-13]. Importantly, there is no reported difference between RPD and OPD in terms of morbidity, mortality, and oncological outcome.

We performed the 1st LPD in the UK in 2011. However, since starting our robotic HPB program in 2017 and performing the 1st RPD in the UK, we have transferred totally from laparoscopic to robotic HPB surgery to expand the number of HPB cases suitable for minimally invasive surgery through the advantages of the Da Vinci system. We believe that this is the best tool currently available for minimally invasive surgery without compromising surgical and oncological outcomes. In the following section, we describe our standardized technique for RPD using Da Vinci Xi or X system based on the largest LPD (n > 100) and RPD (n > 100) series in the UK.

METHODS

How I do it: tips and tricks

We discuss how the RPD is performed using the following steps:

1. Patient selection

2. Patient positioning and port placement

3. Robotic instrumentation

4. Robotic pancreatoduodenectomy

(1) Resection

a. Hilar dissection/division of the gastroduodenal artery (GDA)

b. Transection of the stomach/ duodenum

c. Kocherization and mobilization of the duodenojejunal (DJ) flexure

d. Pancreatic tunneling and resection of the pancreatic neck

e. Transection of the common hepatic duct and cholecystectomy

f. Dissection from the superior mesenteric vein (SMV)/portal vein (PV)

g. Specimen extraction

(2) Reconstruction

a. Pancreatic anastomosis

b. Biliary anastomosis

c. Gastric and jejunal anastomosis

(3) Haemostasis and drains

Patient selection

We are a tertiary referral hospital for cancer patients in London, UK. All our patients undergo extensive staging with CECT, MRI, PET/CT, and EUS for pancreatic cancer and are discussed at the weekly multidisciplinary meeting before resection. Patients with vascular involvement of the superior mesenteric vein and artery are treated with neoadjuvant chemotherapy/chemoradiotherapy followed by restaging. We exclude patients requiring vascular resection for RPD and those who have had multiple laparotomies previously. This is to reduce the conversion rate and risks of intraoperative bleeding. After a multidisciplinary team discussion, patients are assessed by the anesthetic team, dietician, and physiotherapist before the surgery. Patients with jaundice (bilirubin > 250 umo/L) are usually treated with ERCP biliary stenting with SEMS to relieve jaundice before surgery. Biopsies are taken endoscopically and repeated if inconclusive. The surgery is usually performed 4 weeks after the last cycle of systemic neoadjuvant chemotherapy.

Patient positioning and port insertion [Figures 1 and 2]:

The supine position with 15 degrees reverse Trendelenburg is used for RPD, and the table is lowered for better ergonomics for the assistant surgeon. Arms are tucked at the sides of the trunk. The surgical assistant sits or stands between the legs. Pneumoperitoneum is induced with a sub umbilical vertical Hasson technique (Kii Balloon Blunt Tip system 12 × 100 mm, Applied Medical, Netherlands), through which the resected tissue is extracted by enlarging the incision to 4-5 cm in length [Figure 3]. Standard port placement is used with the Si and X system docked from the head of the patient and the Xi system from the side of the patient. The camera port is inserted at 2-4 cm above and lateral to the umbilicus in the right mid-clavicular line, as camera arm or arm 2 should ideally be 20 cm away from the head of the pancreas. Arm 1 is positioned lateral to arm 2 on the right side of the patient, and arms 3 and 4 lateral to arm 2 on 3, respectively, on the left side of the patient. For the X and Xi system, all ports are in the same horizontal line, at least 6 cm apart [Figure 1A]; for the Si system, the ports should be placed in a 'u' shaped and 6 cm apart [Figure 1B]. Further to the above 4 (8 mm bladeless obturator, Da Vinci Xi, Intuitive Surgical, USA) robotic ports, we use a 12 mm port (Kii Fios first entry,12 × 100 mm, Applied Medical, Netherlands) with a minimum of 3 cm below and between arm 1 and arm 2 on the right side of the patient as the assistant's left hand working port. The assistant ports are used for suction, insertion of sutures, swabs, laparoscopic grasper, and staplers. The camera is inserted through arm 2 and targeted at the head of the pancreas. When the robotic EndoWristed stapler is used, a 12 mm port will need to be used for arm 3.

Robotic instrumentation

The standard robotic instrument used after the camera insertion in arm 2 is bipolar fenestrated forceps in arm 1, hook diathermy in arm 3 and Cadiere or Prograsp forceps in arm 4. Arm 3 is where most instrument changes take place, swapping the hook diathermy for the vessel sealer (Vessel Sealer Extend, Da Vinci Xi, Intuitive Surgical, USA), needle holder/suture cutter, hem-o-lok (Weck Hem-o-Lok L, Hem-0-Lok ML, Teleflex Medical, USA) and scissors, as required.

Resection

We modified our RPD based on our extensive experience with OPD over 25 years and LPD over 15 years and standardized it to be consistent with surgical techniques and instrumentation for improved training and clinical outcomes by reducing variations with the following key points for resection following our initial 25 RPD:

(1) Following diagnostic laparoscopy to exclude peritoneal and/or liver metastasis, we start with hilar dissection. However, we avoid cholecystectomy and bile duct transection at the start of the resection to avoid spillage of bile, which requires frequent suction, increasing operative time.

(2) We perform a partial hepatic flexure mobilization in our approach after taking down the hepatocolic ligament over Gerota's fascia by opening the angle between D3 and the colonic mesentery to expose the route of the small bowel mesentery and the origin of the SMV.

(3) The GDA is transfixed with 3/0 prolene suture and clipped with medium-large robotic Hem-o-loks before transection.

(4) The pancreatic crural tissue behind the SMV and lateral to the superior mesenteric artery (SMA) is divided with laparoscopic staplers (Echelon Flex Powered plus articulating endoscopic linear cutter 60 mm, Ethicon, USA) for better hemostasis and prevention of bleeding postoperatively from SMA branches to the pancreas.

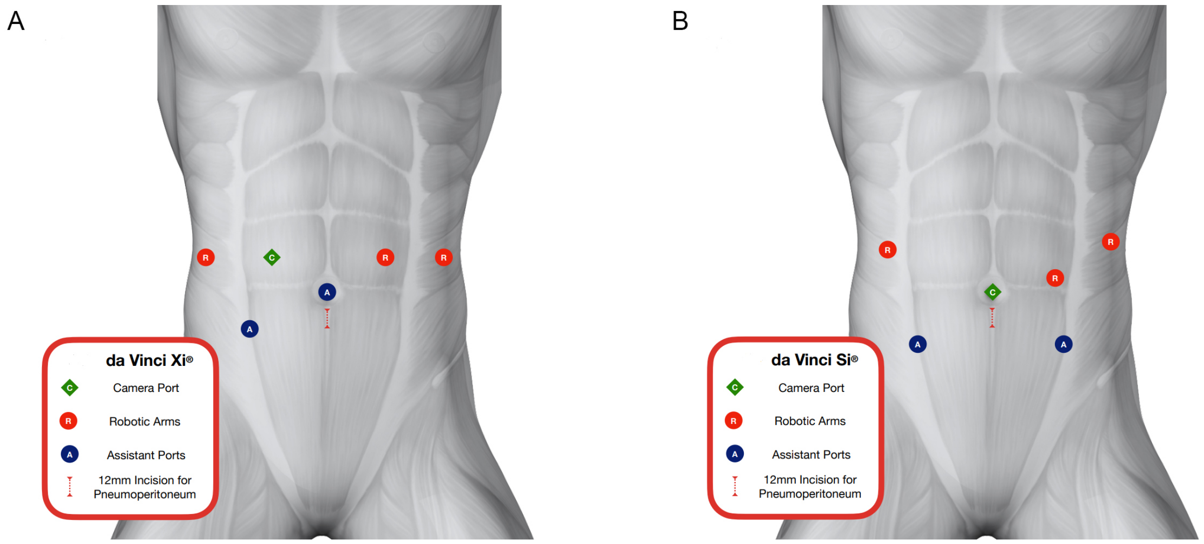

Figure 1. (A)Port positioning for pancreatoduodenectomy using the Da Vinci Xi and X; (B) port positioning for pancreatoduodenectomy using the Da Vinci Si.

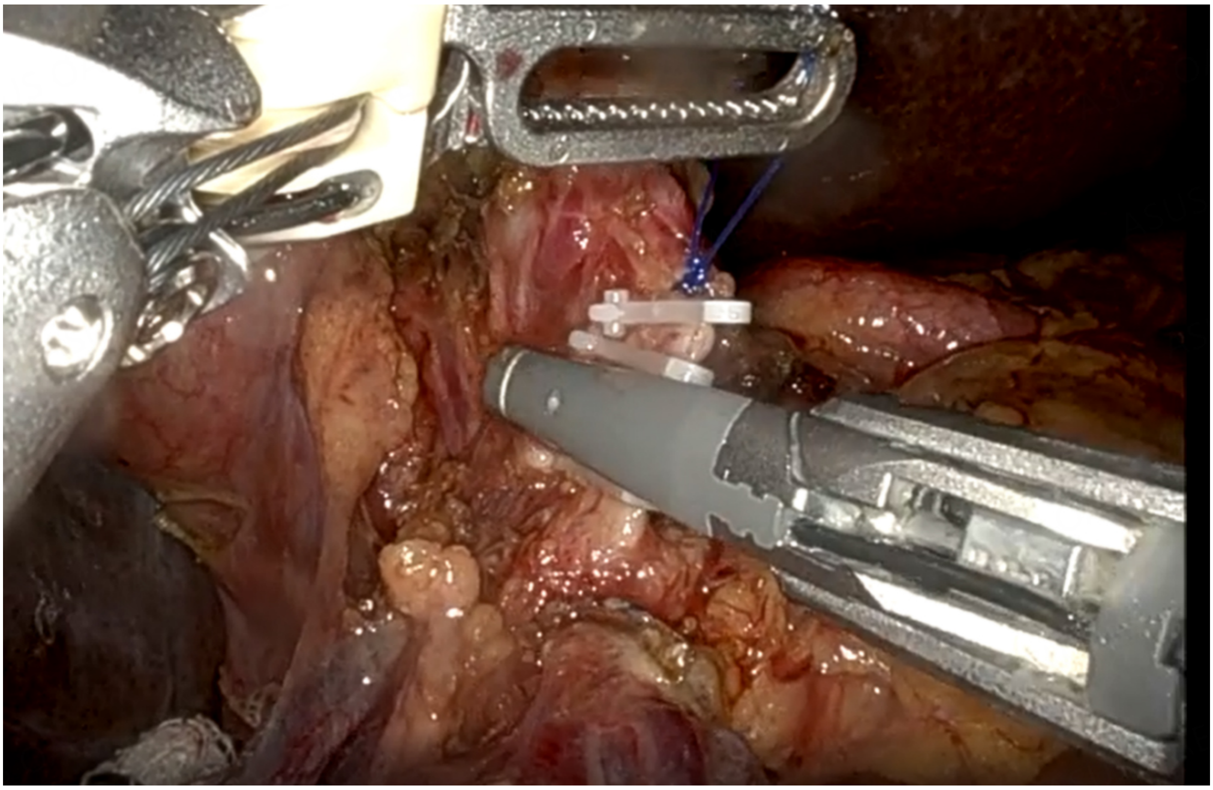

Figure 2. Division of GDA stump.

Hilar dissection/division of the gastroduodenal artery

This is the first step in the RPD. The hilum is exposed after retracting the liver with Cadiere forceps in arm 4. Then lymph node dissection is performed along the coeliac axis, common hepatic, proper hepatic, right hepatic, left hepatic arteries and retro portal area using hook diathermy. The tissue and lymphatics around

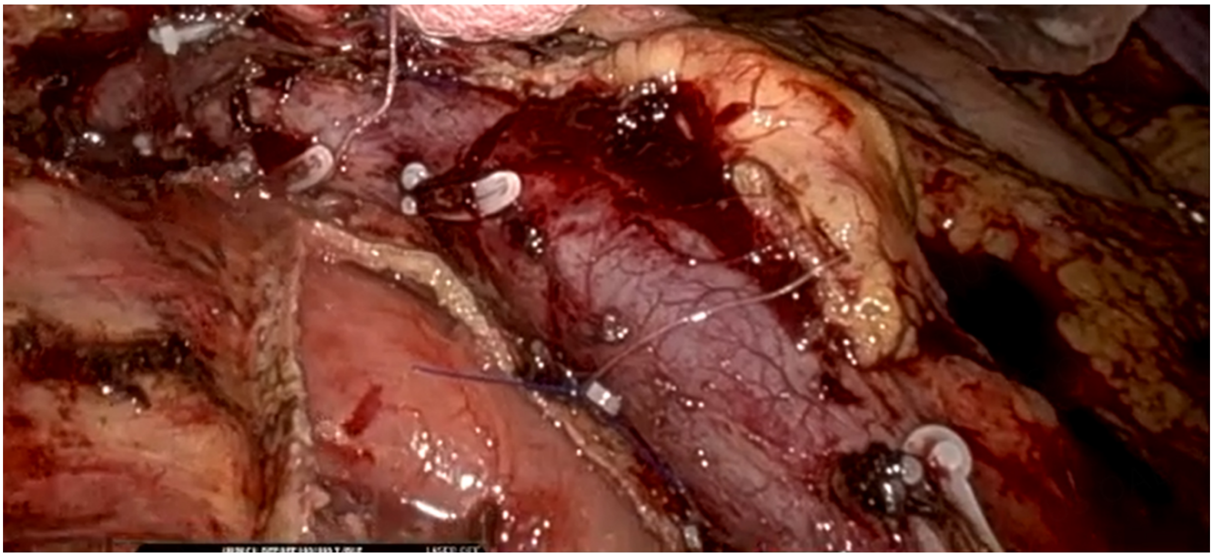

Figure 3. Transection of pancreatic crural tissue.

the hepatic arteries are removed to define the right gastric artery and gastroduodenal artery. Then, a dissection of Calot's triangle is done to delineate the cystic artery and duct. After delineation of the structures, the gastroduodenal artery (GDA) is ligated with 3/0 prolene with the needle holder in arm 3. Then, medium-large hem-o-lok clips are applied to the right gastric artery, cystic artery and gastroduodenal artery, followed by division using the vessel sealer in arm 3 [Figure 2]. During this step, the common hepatic duct is dissected off the upper border of the pancreas in preparation for the division of the pancreas at a later stage. During this step, hepatic artery anomalies must be kept in mind. The author's preference is delineating these anomalous arteries from superior mesenteric arteries after the pancreatic neck transection for better vascular control.

Transection of the stomach/ duodenum

During this step, the body of the stomach is lifted with the use of Cadiere forceps in arm 4. Then using the vessel sealer in arm 3, the gastrocolic ligament is divided followed by the division of the gastro-pancreatic adhesions using hook diathermy. The right gastroepiploic vessels are divided either by using the vessel sealer after applying Hem-o-loks or by using a curved tip Endo GIA 45 mm vascular stapler. Then, the stomach is divided at the level of pylorus in the case of classical Whipple procedure or the first part of the duodenum in the case of the pylorus-preserving pancreatoduodenectomy using the laparoscopic stapler (Echelon Flex Powered plus articulating endoscopic linear cutter 60 mm, Ethicon, USA). After division, the stomach is positioned in the LUQ to keep it away from the field of dissection. Usually, the staplers are introduced by the assistant through the sub-umbilical port.

Kocherization and mobilization of the duodenojejunal flexure

This step is done effectively by retracting the duodenum with the Cadiere forceps in arm 4 towards the patient's left. The Kocher maneuver is completed after exposing the anterior aspect of the vena cava and aorta by dividing the peritoneum around all four parts of the duodenum and visualizing the right renal vein behind the head of the pancreas. Most duodenojejunal (DJ) flexure dissection can be done from the right side of the mesentery. The dissection is greatly aided by the assistant using both assistant ports with suction and a retractor, retracting the colon to the right and duodenum to the left, exposing the DJ flexure from the right side at this stage. Left-sided dissection of the DJ flexure is only considered if there is difficulty in bringing the jejunum over to the right side after Kocherization of the duodenum. The mesentery to the first 15 cm of jejunum is divided close to the mesenteric border using the vessel sealer in arm 3. Then, the jejunum is marked 80 cm from the DJ flexure with 2/0 PDS and brought over to the supracolic compartment and anchored to the anterior abdominal wall in front of the stomach. This step effectively reduces the back-and-forth movement of instruments during later stages of the operation, reducing operative time. Now the camera along with instruments are moved towards the right side of the mesentery and the jejunum is pulled through the retro mesenteric window followed by jejunal transection around 15 cm distal to DJ flexure using the stapler (Echelon Flex Powered plus articulating endoscopic linear cutter 60 mm, Ethicon, USA).

Pancreatic tunneling and resection of the pancreatic neck

During this step, the inferior border of the neck of the pancreas is dissected off the mesentery with hook diathermy to identify and expose the SMV. Subsequently, gentle dissection is carried out behind the pancreatic neck using hook diathermy in combination with mild irrigation and suction by the assistant. Care is taken to avoid bleeding from the venous tributaries to the portal vein during the tunneling behind the pancreatic neck. Dissection at the angle between the CHA and GDA will expose the origin of the PV above the superior border of the pancreatic head. After completion of pancreatic tunneling above the SMV, the neck of the pancreas is divided using the vessel sealer, and hemostasis of the pancreatic remnant is achieved with the use of bipolar fenestrated grasper in arm 1. In the case of inflammatory adhesions around the pancreas, dissection proceeds cranially from the route of the mesentery along the SMV to complete tunneling of the pancreas.

Transection of the common hepatic duct and cholecystectomy

Following pancreatic neck transection, the common bile duct is dissected from the proper hepatic artery using hook diathermy after the application of Hem-o-loks to small blood vessels. Then, the gallbladder is mobilized from the liver bed and the common hepatic duct (CHD) is dissected from the hepatic artery and PV followed by transection of the CHD with hook diathermy. Subsequently, the bile duct along with retro portal and superior pancreaticoduodenal nodes are mobilized from the portal vein to the level of the origin of the SMA.

Dissection from the superior mesenteric vein/portal vein

This is a crucial step in PD. We take considerable care to avoid bleeding from the venous tributaries to the portal vein. The small venous tributaries are delineated using hook diathermy and divided with the vessel sealer after applying medium-large Hem-o-loks on the portal vein side. Larger vessels including the pancreatoduodenal vein tributary of the 1^{st} and 2^{nd} branches of the jejunum and the inferior pancreatoduodenal artery branch from the SMA are secured with 3/0 prolene sutures in addition to Hem-o-loks. After dividing the venous tributaries, the meso-pancreas, and crural tissue is divided behind the superior mesenteric vein (SMV) and portal vein (PV) on the lateral side of the SMA using a stapler [Figure 3] (Echelon Flex Powered plus articulating endoscopic linear cutter 60 mm, Ethicon, USA). During this step, we make sure that the vascular structures are not included in the staple line by keeping the stapler along the course of SMA before firing. With the use of staplers during this step, we have observed a reduction in chyle leak rates and postoperative hemorrhage from the SMA branches without compromising oncological clearance.

Specimen extraction

At the end of pancreatoduodenectomy resection, the swabs are removed, and the spilled bile is suctioned to avoid wound contamination during specimen extraction. In our unit, the 12 mm Hasson cannula in the sub umbilical port is swapped with a 15 mm cannula (Versa One Optical trocar with fixation cannula, Covidien USA) port for insertion of a 15 mm endo bag (Endo Catch II Auto suture, Specimen retrieval pouch,15 mm Covidien, USA) to retrieve the specimen. However, there are several specimen retrieval bags available with a capacity of over a liter (1,200-1,500 mL) that can fit in a 12 mm port without the need to swap for a 15 mm diameter port. The port is removed with the specimen by extending the incision to allow for safe removal. Pneumoperitoneum is released. After extraction of the specimen, the sub umbilical port site incision is closed with loop 0/0 PDS and skin with 2/0 Monocryl subcuticular stitch and covered with a wound dressing before proceeding to reconstruction.

Reconstruction

After the reintroduction of the pneumoperitoneum, the reconstruction proceeds with four robotic arms and one existing assistant port in the right iliac fossa. Once again, we have standardized the techniques for pancreatic, biliary, and gastric anastomosis to be consistent with very little variation. The key points are as follows:

1. Pancreatic anastomosis

a.Visible pancreatic duct-Blumgart technique

b. Non-visible pancreatic duct-pancreaticogastrostomy

2. Biliary anastomosis

a. Duct ≥ 8 mm - end to side with continuous running suture, laparoscopic 3/0 V-Loc or 3/0 FILBLOC

b. Duct < 8 mm - end to side with interrupted 4/0 PDS suture

3. Gastric and jejunal anastomosis

a. Side to side gastrojejunostomy with endo GIA 45 mm

b. Side to side jejunojejunostomy 30cm below GJ with endo GIA 45 mm

Pancreatic anastomosis

Sixty-one different types of pancreatic anastomoses have been described in the literature, which can be divided into three groups: end-to-end pancreatojejunostomy, end-to-side pancreatojejunostomy, and end-to-side pancreaticogastrostomy. However, we have simplified and standardized this to use one technique for the reconstruction of the pancreas based on the visibility of the pancreatic duct to reduce variations and postoperative leaks. Before the anastomosis, the pancreatic remnant is mobilized for up to at least 2cm from the splenic vein, and hemostasis is secured at the cut surface.

(1) Visible pancreatic duct

If the duct is visible, a modified Blumgart technique is used to form an end-to-side pancreatojejunostomy as described for OPD[14]. First, we take a transverse mattress (U stitch) cephalad to the pancreatic duct between the pancreatic remnant and posterior jejunum with a 3/0 PDS suture, the first Blumgart stitch. The needle is kept on the thread at this point. Next, the duct to mucosa pancreatic-jejunal (end to side) anastomosis is completed using 4/0 or 5/0 PDS sutures. Due to the magnification and dexterity of robotic instruments, this anastomosis can be done elegantly, securing the sutures in turn, even in patients with duct sizes of 2-3 mm. Normally we place around four stitches for the posterior wall and three for the anterior. The knots are always placed outside the lumen over a handcrafted internal stent made either from a feeding tube of FG3 or 4, depending on the diameter of the pancreatic duct. After the duct to mucosa anastomosis, two more transverse mattress sutures are placed caudal to the first between the pancreatic remnant and posterior jejunum for further anchoring and hemostasis. Usually, we complete the middle mattress suture on either side of the duct. The three Blumgart stitches are then passed through the anterior jejunum before securing each in turn. A recent publication reported that modified Blumgart anastomosis in robotic pancreatoduodenectomy is a simple and safe procedure that provides non-inferior surgical outcomes compared to open technique[14].

(2)Non-visible pancreatic duct

In the case of a non-visible pancreatic duct, the pancreatic remnant is mobilized at least 4 cm off the splenic vein, which allows the tension-free anastomosis of the pancreatic remnant to the posterior wall of the stomach. After the pancreatic mobilization, hemostatic sutures are applied to the pancreatic cut surface using 3-0 PDS. Then, a 2 cm gastrotomy is made in the posterior wall of the stomach using hook diathermy. Subsequently, anchoring sutures were made between the anterior wall of the pancreas (3 cm away from the cut margin) and the posterior wall of the stomach on the proximal side of gastrotomy) using 3/0 PDS. Then, an anterior gastrotomy is made just opposite the posterior gastrotomy. With the use of graspers through the anterior gastrotomy, the pancreatic cut surface is pulled inside the gastric lumen for about 1.5-2 cm. After stabilizing the pancreatic cut surface, the posterior surface of the pancreas is sutured with the posterior wall of the stomach distal side of the gastrotomy using 3/0 PDS. Then, through the anterior gastrotomy, the pancreatic remnant is sutured on the gastric lumen side with 3/0 PDS. After complete hemostasis, the anterior gastrotomy is closed with 3-0 PDS (Pancreaticogastrostomy for soft pancreas without a visible pancreatic duct, pulling technique)[15].

Biliary anastomosis

The common hepatic duct stump is mobilized from the right hepatic artery to avoid inadvertent stitches in the artery. Bile duct hemostasis is secured and flushed with saline to remove the debris to prevent the risk of postoperative cholangitis. Duct to mucosa hepaticojejunostomy is reconstructed at 20 cm distal to the pancreaticojejunostomy over a handcrafted plastic stent made from a feeding tube of FG3 or 4 for ducts less than 8 mm. If the duct size is over 8 mm, we use continuous sutures for the posterior wall using 3/0 FILBLOC (Assut Europe, Italy) or 3/0 V-Loc (Covidien, USA) and interrupted sutures for the anterior wall using 4/0 PDS. If the duct is less than 8 mm, we prefer interrupted sutures for both the anterior and posterior walls with 4/0 PDS. Following the hepaticojejunostomy, we anchor the jejunum to the retroperitoneum distal to the anastomosis. At the end of this step, fluid around the anastomosis and swabs are removed.

Gastric anastomosis

This anastomosis is reconstructed at 60 cm distal to hepaticojejunostomy in the antecolic fashion. During this step, the anchoring stitch of the jejunum to the anterior abdominal wall, completed in the earlier part of the operation, is removed and the jejunum is moved towards the posterior wall of the stomach. Then, an enterotomy is made in the jejunum, and a gastrotomy in the posterior wall of the stomach for stapler insertion. Through the assistant port, the stapler (Endo GIA Articulating reload with Tri-staple technology 45 mm vascular/medium, Covidien) is inserted and the gastro-jejunal anastomosis is made after placing the thicker blade on the stomach side and thinner blade on the jejunal side. The enterotomy is closed with a continuous suture using 3/0 FILBLOC or V-Loc. During this anastomosis, the Cadiere forceps in arm 4 are used for stabilizing the stomach.

Jejuno-Jejunostomy

This anastomosis is reconstructed at 30-40 cm distal to hepaticojejunostomy and 15-20 cm proximal to gastrojejunostomy using straight endo GIA 45 mm stapler inserted through the assistant port after making enterotomy using hook diathermy. Then the enterotomy is closed using 2/0 FILBLOC or V-Loc. The Cadiere forceps in arm 4 is used to stabilize the jejunum during this step. This completes the reconstruction after RPD.

Hemostasis and drains

At the end of reconstruction, hemostasis is checked around the anastomoses, and the fluid is suctioned. Two 20 FG Robinson drains are inserted through arms 1 and arm 4 after the swab and instrument count after the de-docking of arms 1 and 4. The right drain is placed in the right subhepatic space and the left drain is placed is placed over the left subhepatic space covering the anterior aspect of pancreatic-jejunal anastomosis. Finally, the de-docking of arms 2 and 3, and the removal of ports is completed. The skin is closed with 3/0 monocrystal and the wound is dressed [Figure 4].

Operation time, conversion to open PD, and blood transfusion

Although some series report a longer mean operating time for RPD compared with OPD, a meta-analysis of RPD *vs.* OPD involving a total of 680 patients did not find any significant difference in operating time[16]. The median operating time for our whole RPD series was 287 min, with a lower conversion rate to open operation compared with LPD[17]. In our updated robotic series of over 100 RPD, our conversion rate was 5.3%. Only two patients in our series had an estimated blood loss of > 500 mLs and required a perioperative blood transfusion. This is consistently reported as a major advantage for minimally invasive PD[8,11-13].

Postoperative complications and length of stay

Minimally invasive procedures do not result in a perioperative cortisol peak compared to a cortisol surge in open surgery, irrespective of procedure duration[18]. Therefore, despite potentially longer operating times, there is likely a reduced surgical stress response in robotics compared to the OPD. Also, they require reduced use of analgesics compared to OPD procedure. Respiratory complications are rare in RPD due to the avoidance of retractors as in open surgery. The wound complications are reduced due to the use of regular endo-bags. To reduce wound complications, we are covering the umbilical port with betadine-soaked gauze at the time of specimen extraction. We have observed that patients who undergo RPD are less aware of the magnitude of the surgery and are well motivated to mobilize from day one of the postoperative period, which reduces the respiratory complications and early return of bowel movement. An improvement in length of stay for robotic compared to open PD has been observed in meta-analyses[19,20], and may also be shorter compared to laparoscopic PD[17].

Morbidity, mortality, and oncological outcomes

There is no significant difference in morbidity and mortality between RPD and OPD, with the published review articles reporting a serious morbidity of 21.14% ± 6.95% with postoperative pancreatic fistula (POPF) of 20.39% ± 9.64% and 90-day mortality of 3.45% ± 1.37%[19,20]. Our series showed a morbidity rate for Clavien-Dindo > 2 of 27.1%, with one mortality from myocardial infarction on postoperative Day 7 (0.83%). All our POPF were biochemical grade A leaks[17]. This may be due to the precision of the robotic instruments and suturing with a magnified view with less trauma from handling the pancreatic remnant. Also, the drains are kept until they become dry. The drain amylase level is routinely measured prior to their removal in patients who continue to drain after 21 days. There was no gastric or jejunal anastomosis leak in

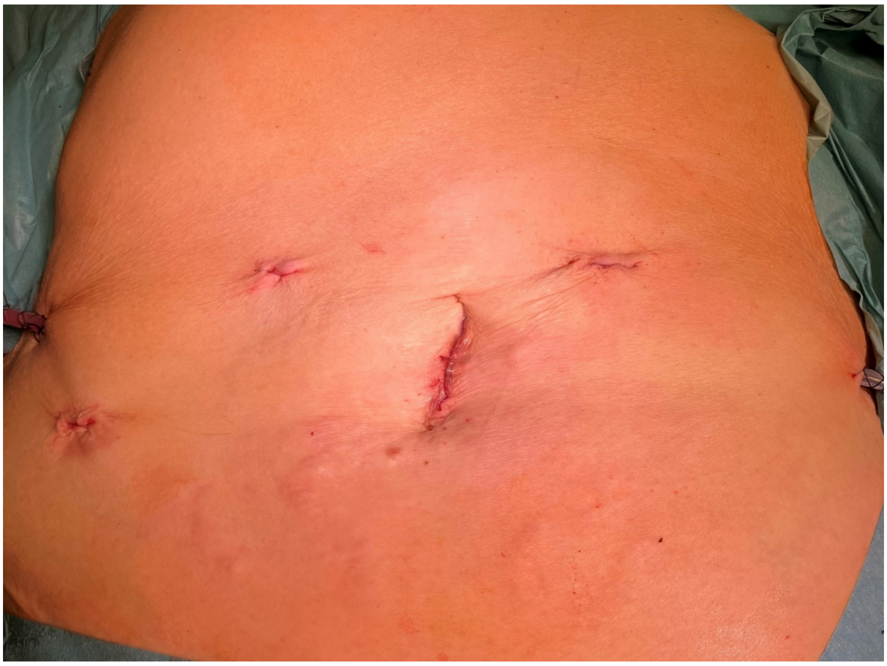

Figure 4. Incisions for extraction and port positioning for pancreatoduodenectomy using the Vinci Xi/X with arms 1 and 4 replaced with FG18 Robinson's drains.

our series. We had a bile leak rate of 6.3% in our first reported series[17], all managed conservatively, which had reduced significantly to 2.1% after 100 RPD cases. The oncological outcome following RPD based on R status and the number of lymph nodes harvested showed an R0 resection rate of 89.24% ± 11.95% with a mean tumor size of 25.62 ± 3.50 mm and an average number of resected lymph nodes of 22.47 ± 10.37 respectively[17], more than the 15 recommended by the European Society for Medical Oncology (ESMO)[21].

ROBOTICS HPB SURGERY AND AI

There is little doubt that the future of surgery will be minimally invasive to avoid major trauma to patients for faster recovery, which will inevitably offset the cost of robotic surgery. Advances in technology will enable us to achieve this with the precision of robotic instruments and improved ergonomics leading inevitably to the development of haptic feedback and artificial intelligence[22]. Through robotic data acquisition, it will be much faster for machine learning and deep learning to develop the next generation of intelligent surgical robots to personalize surgical plans and procedures, reducing intraoperative errors and standardizing complex operations such as PD. Furthermore, with AI, performance metrics can be applied to future clinical practice to be used as competency tools to assess the performance and quality of a surgeon's skills rather than conventional morbidity and mortality data[23]. Robotic and AI training should be embedded in the surgical training curriculum for the future generation of surgeons to benefit patients directly and also to encourage research collaboration for developing future intelligent robotic surgery.

Robotic surgery is a safe approach for patients requiring PD, and it may offer advantages over both open and laparoscopic surgery. However, randomized controlled trials are still required to prove this. Notably, the superiority of performing either a pancreaticogastrostomy or Roux-en-Y pancreaticojejunostomy has never been shown in the open pancreatic surgical literature[24]; as a result, it is doubtful that future will be able to show the superiority of either anastomosis in the robotic literature. Perhaps the most promising advantage of current robotic surgery will be its ability to incorporate more artificial intelligence in the future, specifically, more autonomous actions. An emerging question is whether handheld robotic devices will enable a safer and more rapid adoption of surgical autonomy[25].

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the study and performed data analysis and interpretation: Jiao LR

Performed data acquisition, as well as provided administrative, technical, and material support: Vellaisamy R, Gall T

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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