Journal of Gastrointestinal Surgery (2019) 23:1661–1671
https://doi.org/10.1007/s11605-019-04266-1

HOW I DO IT

How I Do It: Robotic Pancreaticoduodenectomy

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Received: 28 February 2019 / Accepted: 10 May 2019 / Published online: 30 May 2019

Introduction

Beginning in 2008, our group embarked on a systematic approach to develop and modify the robotic pancreaticoduodenectomy (RPD). Since that time, over 600 RPDs have been performed at the University of Pittsburgh. Early studies (2008–2012) focused on safety and feasibility.[1–3] This was followed by identification of the learning curve which is estimated at 80 cases for novice adopters (2012–2014). Once we established benchmarks of excellence, we proceeded with multi-institutional comparative effectiveness studies of RPD versus standard open pancreaticoduodenectomy (2014–2016); some of which have demonstrated beneficial outcomes to the robotic approach, such as reductions in blood loss and morbidity.[4, 5] Finally, over the past few years (2016–present), we focused on implementing a dedicated training program to facilitate safe dissemination.[6]

Throughout this time period, various technical modifications have been incorporated into the procedure, with the overall aim of reducing operating time, curtailing morbidity, and improving oncologic outcomes. In this article, we review the technical aspects of RPD as it is performed by our group today. Although the principles of the operation are similar to OPD, the sequence of steps and the role of the assistant are radically different. Our aim here is to provide the reader with a detailed account of the technical steps of this complex operation, while emphasizing that keys to successful results are patient selection, team approach, and a fundamental understanding of the principles of open pancreatic surgery.

Our indications for RPD are similar to those of open pancreaticoduodenectomy with a few important exceptions. Most RPDs are for periampullary malignancy, but it can be performed for premalignant cystic lesions as well as chronic pancreatitis—although the latter can be challenging. While there are no absolute contraindications for robotic pancreaticoduodenectomy in experienced hands beyond the learning curve, there are several relative contraindications, particularly for early adopters. The following are important considerations:

1- Preoperative imaging: All patients should be evaluated with a high-quality triphasic computed tomography scan prior to surgical decision-making. The tumor vessel interface must be thoroughly evaluated to determine any vascular involvement prior to determining operative approach. Patients with vascular involvement requiring venous or arterial reconstruction are not offered a robotic approach and are resected with a standard open operation. Our vascular resection rate is approximately 15%, but most of these are tangential side bite resections (stapler or repair of venorrhaphy). Importantly, even these were only attempted after the learning curve (80 cases) was surmounted and are only performed with an experienced bedside assistant. Venous resection adds another level of complexity to an already demanding procedure and is not recommended early on in the learning curve.

2- Pathology: Although non-pancreatic ductal adenocarcinoma cases seem ideal from a resection standpoint, they represent difficult reconstructions given the small caliber of hepatic and pancreatic ducts and soft pancreatic gland, leading to increased bile and pancreatic leaks for early adopters. Conversely, pancreatic ductal adenocarcinomas may seem daunting to resect but typically have more favorable reconstruction with dilated ducts and a firm gland. Ideal cases for RPD are small pancreatic adenocarcinomas with a classic double-duct sign (facilitate easy pancreatic and biliary reconstruction) and no evidence of local vascular invasion. Once the surgeon is facile at suturing small biliary and pancreatic anastomoses (20–40 cases as shown by our learning curve analysis), then selection criteria can be expanded to any periampullary lesion with no vascular invasion.[1]

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3- Previous abdominal surgery: Prior upper abdominal surgery is not a contraindication, but we advocate avoiding cases with prior upper gastrointestinal reconstructions, such as gastrectomy with Billroth II or Roux-en-Y reconstruction, including gastric bypass procedures. Orientation of the small intestines robotically can be tricky in these circumstances, and excessive manipulation of the small intestines can lead to unrecognized bowel injury due to lack of haptic feedback, particularly within the learning curve phase. Additionally, since RPD is generally associated with longer operative times, cases requiring extensive adhesiolysis are avoided.
4- Body habitus: In general, RPD should be avoided for extremes of BMI. Patients with small "transverse diameter" and those with a BMI < 20 can be challenging due to lack of adequate space for port placement (see next section). Similarly, since our technique entails substantial mobilization of the right colon and transverse mesocolon (see next section) and division of the ligament of Treitz from the right supracolic location, these critical steps can be challenging in patients with a BMI > 40.
5- Presence of experienced bedside assistant: The role of the bedside assistant cannot be overemphasized, particularly during the learning curve phase. The bedside assistant is active in all phases of the resection similar to open surgery. Early on, we advocate that the bedside assistant is a fellow HPB attending rather than a trainee (fellow or resident). Many who critique this requirement have not been able to expand their selection criteria and have very long operative times.
6- Availability of experienced open pancreatic surgeon: In the event of bleeding and the need for an emergent conversion, the availability of an experienced pancreatic surgeon (on site/campus) versatile in vascular reconstruction is critical. Conversions for bleeding from the SMV/portal vein are a "3 person" division of labor: one surgeon to tamponade bleeding using the assistant ports while 2 surgeons are needed to undock the robot, create a laparotomy, and place a self-retaining retractor (Thompson, Bookwalter etc.)

Surgical Technique

Patient Positioning

After induction of general anesthetic, a Foley catheter and orogastric tube are placed. Arterial line placement for intraoperative monitoring is routine; however, central venous lines are placed in selected patients only. The patient is positioned on the split-leg table by tucking the right arm and extending the left arm to 60° on an arm board. All pressure points are padded to prevent injury during the procedure. Special attention is paid to the tucked right arm which is padded with a Pigazzi pink pad (Xodus Medical, New Kensington, PA). Both legs are abducted to position "B" on the split-leg attachments. Additional padding is placed posterior to both knees at the break in the table to avoid hyperextension of the knee. Circumferential straps are used around the chest and both legs anchoring the patient to the table since the majority of the procedure is done in a steep Trendelenburg position. The operative table is rotated to 45° away from the anesthesia machine so that the da Vinci SI robot (Intuitive Surgical, Sunnyvale, CA) can be docked at the head of the table (not necessary for XI platform, which can be docked from the side of the patient).

Diagnostic Laparoscopy and Trocar Placement

The following port configuration applies to the platform. Access to the abdomen is obtained under direct visualization through a 5-mm zero-degree scope and optical separator trocar incision in the left upper quadrant, one hand breadth (8–10 cm) to the left of the midline (along the left midclavicular line), 3 cm above the umbilicus. Pneumoperitoneum is achieved, and the abdomen is distended to a pressure of 15 mmHg. A diagnostic laparoscopy is performed to assess for any metastatic disease. After diagnostic laparoscopy, the remainder of the seven ports are placed under direct visualization as shown in Fig. 1: The camera port which consists of a 12-mm laparoscopic trocar is placed 2 to 3 cm above and to the right of the umbilicus (in the same transverse line as the optical separator). Next, two robotic 8 mm trocars are placed in the right side of the abdomen in the mid-clavicular (R2) and anterior axillary (R3) lines along the same transverse line of the optical separator and the camera. The original access (optical separator) trocar is swapped out for the third 8-mm robotic trocar (R1). Next, the two assistant trocars are placed. The first is a 5-mm trocar which is placed a hand-breadth below the camera trocar and in a line bisecting the 12-mm camera trocar and the 8-mm robotic R2 trocar located in the right mid-clavicular line. The second assistant port is a 12-mm trocar which is placed one hand-breadth below the camera trocar in a line bisecting the 12-mm camera trocar and the robotic R1 trocar located in the left mid-clavicular line. Care is taken to avoid the inferior epigastric vessels in both quadrants.

The final 5-mm trocar is placed in the left upper quadrant along the anterior axillary line just inferior to the left cost margin. A Mediflex liver retractor (Mediflex® Surgical Products, Islandia, NY) is placed through this trocar for cephalad retraction of the liver. The Mediflex retractor has several moving parts and requires some practice, but we have found it to provide superior retraction of the entire liver throughout the case. Once all the trocars have been placed, we proceed with

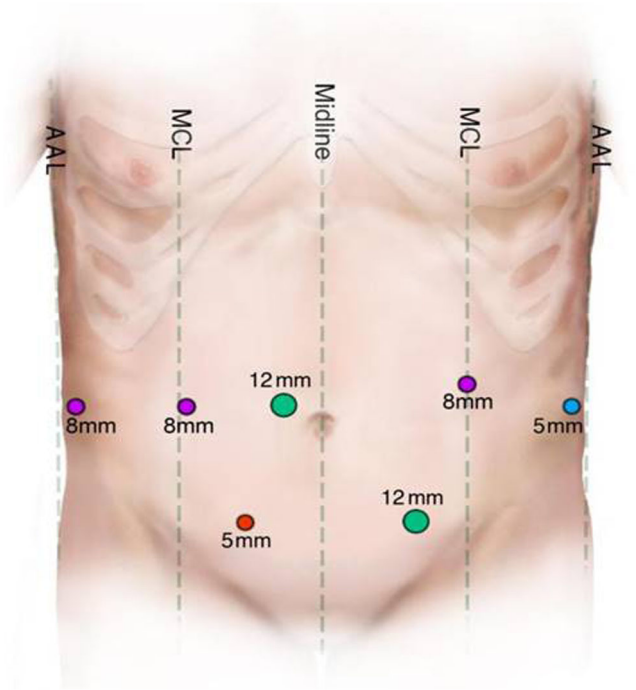

Fig. 1 Port placement for robotic pancreaticoduodenectomy

docking of the SI robot. The robot is docked at the head of the operative table with two robotic arms on the patient's right side, one robotic arm on the patient's left side, and the 12 mm robotic camera placed through the supraumbilical 12-mm trocar. Overall, docking takes 5–10 min in experienced hands. We continue to utilize the Si system in favor of the newer Xi model for the superior visualization with the larger SI camera.

Optimal trocar placement is essential for a successful procedure. The trocar placement outlined previously and depicted in Fig. 1 is our standard placement for normal and slightly overweight patients (BMI 25–35 approximately). For patients with higher BMI and those with centripetal obesity, we tend to shift all of the trocars cephalad by approximately 3–5 cm. For thinner and smaller patients (BMI < 25), we shift all of the trocars down approximately 3 cm with the camera trocar now lying at the level of the umbilicus. An important trick is to maintain at least one hand-breadth between all robotic trocars for all variations in the setup.

Resection Phase

The initial dissection requires important coordination between the robotic surgeon and the bedside assistant. During resection, the following instruments are utilized: R1, hook monopolar (majority of the dissection), occasionally Maryland forceps for getting around vascular structures; R2, fenestrated bipolar; R3, ProGrasp; assistant trocars, combination of blunt tip 5-mm LigaSure (Covidien, Mansfield, MA), 5-mm suction irrigator (Stryker, Kalamazoo, MI), and atraumatic laparoscopic graspers. The instruments used for each of the operation are listed in Table 1.

Step 1: Mobilization of the Right Colon, Kocherization of the Duodenum, Division of the Ligament of Treitz

The lesser sac is entered through the gastro-colic ligament using a combination of the hook monopolar and fenestrated bipolar inferior to the right gastroepiploic vessels. The omentum is transected using the LigaSure to seal any omental vessels encountered during the dissection. Throughout this portion of the dissection, the stomach is retracted anteriorly and cephalad with the ProGrasp from R3. All posterior gastric adhesions to the pancreas are dissected free. Coursing distally along the greater curvature, the transverse mesocolon is dissected/lowered from the gastroepiploic vein pedicle, and the dissection proceeds to mobilization of the hepatic flexure. Care should be taken not to avulse the middle colic or gastroepiploic veins. A near Cattell-Braasch mobilization is performed with mobilization of the entire right colon and hepatic flexure. This allows full access to duodenum for kocherization. The Kocher maneuver mobilizes the duodenum with identification of the inferior vena cava, left renal vein, and ligament of Treitz. During this portion of the dissection, the console surgeon retracts the duodenum anterior and cephalad rotating it out of the retroperitoneum towards the left upper quadrant with R3. In this manner, attachments to the duodenum can be taken with a combination of blunt and electrocautery dissection. The assistant maintains retraction of the hepatic flexure and transverse mesocolon towards the left lower quadrant. This step is particularly difficult for new adopters. One way to ensure its successful completion is to have a dynamic bedside assistant to rotate the colon from the right upper quadrant to the left lower quadrant (Fig. 2).

One key step in the robotic approach is division of the ligament of Treitz from the patient's right side. As the distal duodenum is mobilized, the ligament of Treitz is transected providing complete mobilization of the duodenum and allowing the proximal jejunum to move into the right upper quadrant through this defect (in contrast to open pancreaticoduodenectomy where the ligament is divided from below the transverse mesocolon on the patient's left side). Approximately 30 cm of jejunum is then "eviscerated" into the right supra colic compartment and a window is created in the jejunal mesentery so that the proximal jejunum can be divided 10 cm from the duodenojejunal ligament with an endo GIA stapler, 60 mm gold staple load (Covidien, Mansfield, MA). The mesentery is sequentially divided using the LigaSure up to the inferior border of the uncinate. It is important to completely divide the mesentery up to the uncinate process so that SMV/PV dissection can be safely performed later in the operation.

Table 1 Robotic pancreaticoduodenectomy instrumentation

Steps of the operation	Robotic arm 1 (R1)	Robotic arm 2 (R2)	Robotic arm 3 (R3)	Assistant
Step 1. Mobilization of the right colon, kocherization of the duodenum, division of the ligament of Treitz	Hook monopolar Cadiere forceps	Fenestrated bipolar forceps	*Prograsp* forcep	*LigaSure* Duckbill grasper Suction irrigator Endo GIA stapler
Step 2. Porta-hepatis dissection	Hook monopolar Maryland bipolar forceps	Fenestrated bipolar forceps	*Prograsp* forcep	LigaSure Suction irrigator Endo GIA stapler EndoCatch 10 mm
Step 3. Superior mesenteric vein/portal vein dissection and pancreatic transection	Hook monopolar Maryland bipolar forceps *HotShears*	Fenestrated bipolar forceps	*Prograsp* forcep	LigaSure Suction irrigator Endo GIA stapler
Step 4. Uncinate dissection	Hook monopolar Maryland bipolar forceps	Fenestrated bipolar forceps	*Prograsp* forcep	LigaSure Suction irrigator Endo GIA stapler EndoCatch 15 mm
Pancreaticojejunostomy	Large *SutureCut* needle driver *HotShears*	Large needle driver	*Prograsp* forcep	Duckbill grasper Suction irrigator
Hepaticojejunostomy	Large needle driver *HotShears*	Large needle driver	*Prograsp* forcep	Duckbill grasper Suction irrigator
Gastrojejunostomy	Large *SutureCut* needle driver Cadiere forceps	Large needle driver Fenestrated bipolar forceps	*Prograsp* forcep	Duckbill grasper Suction irrigator

Step 2: Porta-Hepatis Dissection

The pars flaccida is opened and the gastrohepatic ligament is widely divided. Careful dissection is important to avoid transection of a replaced or accessory left hepatic artery. The ligament is divided inferiorly to the lesser curvature of the stomach. Gastric vessels along the lesser curvature are controlled with bipolar electrocautery and the LigaSure. The stomach is then divided with the endo GIA stapler with 60 purple loads just proximal to the pylorus. This division provides optimal exposure to begin the porta dissection. The distal transected portion of the stomach is rotated laterally into the RUQ with the Prograsp in R3. This move "opens up" the porta hepatis and provides sufficient tension for a safe porta dissection. The hepatic artery lymph node (station 8A) is identified and dissected from the common hepatic artery starting from right to left using the robotic hook. The main feeding vessels to this lymph node emanate from the celiac trunk and are ligated with LigaSure to avoid unnecessary bleeding. The lymph node is sent for permanent pathologic evaluation. The dissection is carried laterally to identify the right gastric artery. This vessel is doubly clipped with a 5-mm Endo Clip (Covidien) by the bedside assistant and divided (Fig. 3).

Removal of the hepatic artery lymph node allows identification of the common hepatic artery (CHA), gastroduodenal artery (GDA), and portal vein (PV). We use a strict "no-touch technique" when dissecting those 3 vascular structures. A closed bipolar grasper lifts the CHA to provide tension so that the lymphatic tissue can be dissected off the portal vein. Next, the GDA is dissected circumferentially with the hook and the vessel is looped. Operative vascular anatomy is confirmed with high-quality preoperative imaging; however, if there is any concern regarding aberrant anatomy, intraoperative robotic ultrasound and Doppler flow are used to confirm pulsatile flow in the hepatic arteries after clamping the GDA. The GDA is transected with a 45-mm gold staple load angled tip. A 10-mm Endo Clip is placed on the GDA stump to mark its location.

Throughout this porta dissection, the console surgeon progressively retracts the transected stomach stump more laterally (to the right) to maintain tension as the tissues in the porta are serially divided. The common bile duct is then dissected circumferentially. The use of the hook cautery (R1) and bipolar grasper (R2) allows for a precise and hemostatic dissection. The CBD is pulled laterally (to the right), and the robotic hook works in the plane between the CBD and the PV clearing all the intervening tissue. Occasionally, a portal tributary is encountered and is transected using the LigaSure. The CBD/CHD is transected with the Endo GIA stapler, 45-mm gold staple load with angled tip. We have found that this technique minimizes unnecessary bile spillage during the rest of the dissection. Now that all the structures of the porta have been

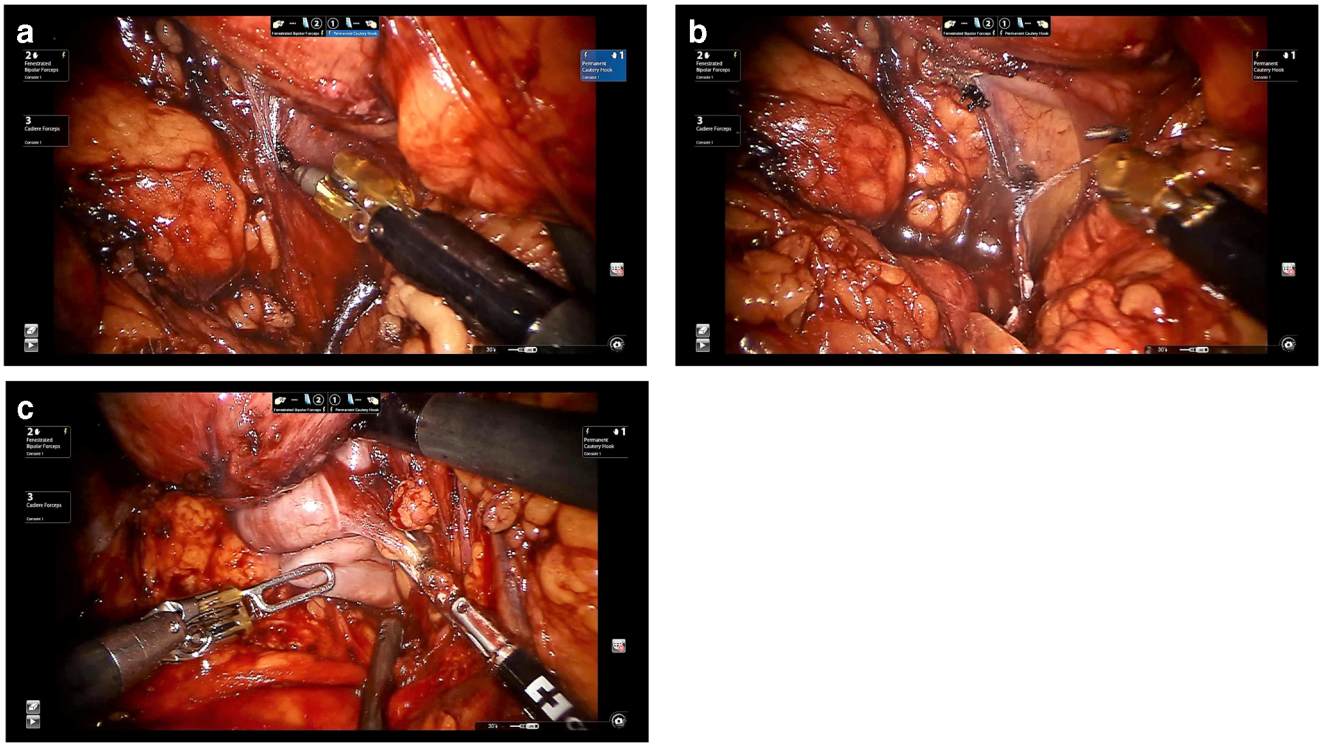

Fig. 2 Division of the ligament of Treitz from the patient's right. This step is a critical portion of the initial dissection. After kocherization of the duodenum, the fibers of the ligament of Treitz are divided with the hook cautery (**a**). Exposure is maintained with R2 retracting the fully mobilized duodenum "up and out" of the retroperitoneum while the assistant is retracting the right colonic mesentery in both the caudal and medial (left) directions. Once the final fibers of the ligament are divided, a tunnel is seen entering the infracolic abdomen (**b**). The jejunum can then be brought through this tunnel into the right upper quadrant (**c**)

identified, we continue the dissection inferiorly along the anterior border of the PV heading caudally towards the pancreatic neck. The lymphatic tissue along the superior border of the pancreas is transected. This move provides a "landing zone" for pancreatic transection and facilitates creation of the retropancreatic tunnel.

Step 3: Superior Mesenteric Vein/Portal Vein Dissection and Pancreatic Transection

This dissection begins at the inferior border of the pancreas. The dissection is accomplished by the console surgeon again using the hook cautery (R1) and the fenestrated bipolar grasper (R2). Prograsp grasper (R3) continues to provide lateral retraction of the duodenum and specimen staple line. The direction of retraction however is now "up and out" into the RUQ, putting the gastroepiploic vein under constant stretch as it enters the SMV. Again, as in step 2, this retraction needs to be adjusted frequently during this portion of the procedure (Fig. 4).

The first move is to identify the SMV at the infra-pancreatic border using the robotic hook, with R2 (bipolar forceps) retracting the inferior pancreatic edge anteriorly and superiorly. Once identified, the dissection continues inferiorly along the anterior surface of the SMV. It is important to identify the right gastroepiploic vein, middle colic vein, and trunk of Henle (right venous branch of the middle colic vein usually joins into the gastroepiploic vein before entering the SMV). This common venous trunk is divided with the LigaSure after multiple sequential burns. We have found that clips or ties have been ineffective and can "rub off" during the course of the operation. Next, the retropancreatic tunnel is created; the pancreas is carefully elevated off the SMV using the closed jaws of the fenestrated bipolar and the hook is used to gently push down on the SMV. The dissection proceeds in a cephalad direction until the previously described supra-pancreatic dissection is reached, thereby completing the retropancreatic tunnel.

Next, the neck of the pancreas is divided. The assistant places a blunt instrument (suction irrigator or atraumatic grasper) in the tunnel with gentle downward traction to protect the SMV/PV during parenchymal transection. The inferior and superior transverse pancreatic arteries are pre-coagulated with the fenestrated bipolar (R2). The pancreatic parenchyma is then divided with "hot" robotic monopolar shears until the level of the pancreatic duct. The pancreatic duct is divided sharply without the use of electrocautery to avoid thermal injury.

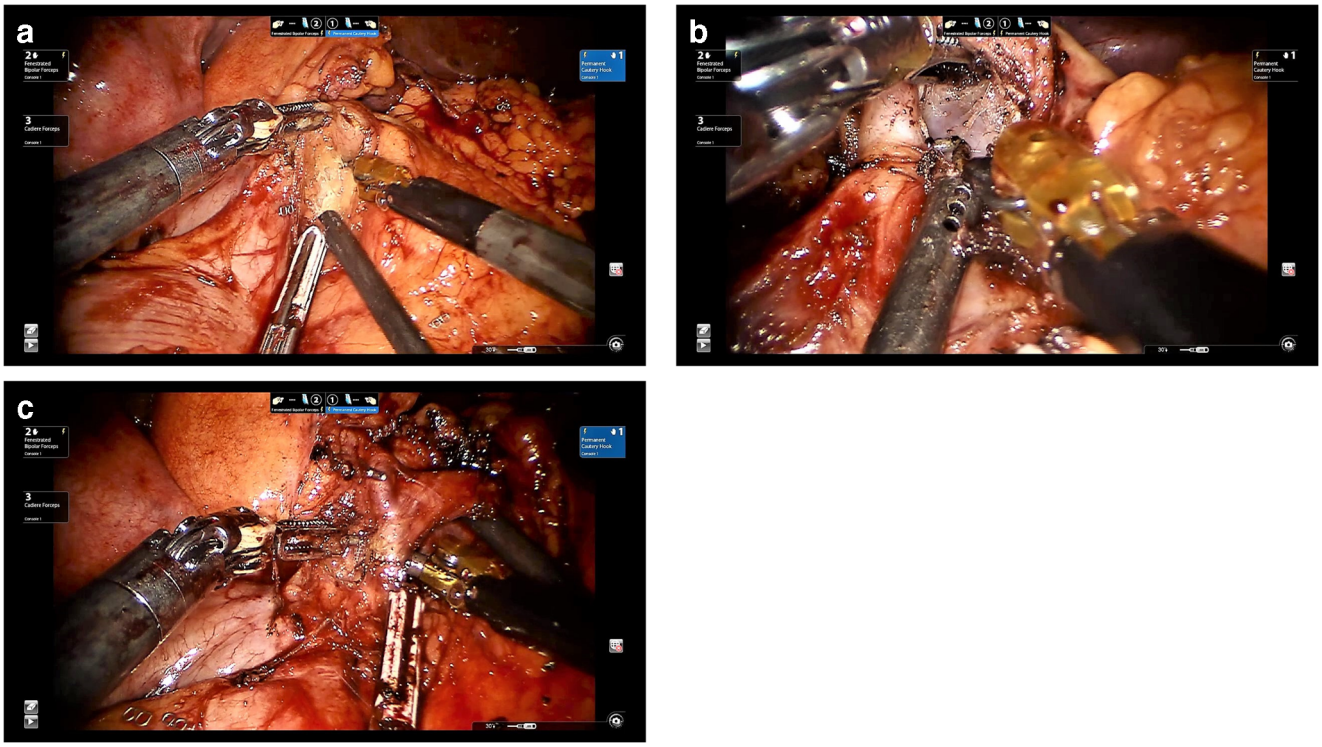

Fig. 3 Porta hepatis dissection. Exposure for this dissection starts with R3 grasping the transected distal stomach and retracting it laterally into the right upper quadrant. The assistant provides counter-traction in a caudal and downward direction. The tissue surrounding the hepatic artery lymph node is grasped allowing dissection and removal of this lymph node (**a**). With the lymph node removed, the portal vein and medial border of the gastroduodenal artery are identified (**b**). R2 provides cephalad retraction on the common hepatic artery. Next, the gastroduodenal artery is dissected circumferentially in preparation for ligation (**c**). The clips from division of the right gastric artery are seen just superior to the hook electrocautery

Step 4: Pancreatic Head and Uncinate Dissection

We view this dissection occurring in 3 layers. The first layer consists of the anterior uncinate layer (Fig. 5a). In this layer, it is important to identify the superior pancreaticoduodenal vein (vein of Belcher, Fig. 5b) as well as the first jejunal venous branch as it enters the SMV. Dissection begins with retraction of the specimen to the right lateral abdominal wall (analogous to the open surgeon's left hand) using R3 to provide tension "to open up the uncinate" for safe dissection (Fig. 5c). The robotic surgeon uses the hook monopolar (R1) and fenestrated bipolar (R2) to divide the small filamentous fibers connecting the SMV/PV to the uncinate. The bedside assistant provides leftward traction on the PV/SMC with a blunt instrument and occasionally uses the LigaSure for small vessel ligation. The superior pancreaticoduodenal vein of Belcher is typically encountered and divided with multiple fires of the LigaSure. The first jejunal branch is also encountered in this layer inferiorly and should be preserved when possible. Small uncinate tributaries of the first jejunal vein are taken with the LigaSure or bipolar (R2). This dissection needs to proceed with extreme caution as avulsion of those small veins can lead to significant hemorrhage from the first jejunal vein.

Once the first jejunal vein is reflected to the left, the dissection of the second (SMA) layer is performed (Fig. 5c,d). This is best accomplished with careful dissection using the hook electrocautery staying anterior and slightly to the right of the SMA. Optical magnification with the robotic camera provides clear visualization of the SMA so that a proper SMA dissection can be performed immediately adjacent to the artery (plane of Leriche) maximizing the retroperitoneal margin just as it would be performed in an open operation. Key portions of this dissection are depicted in Fig. 5. This portion of the dissection is aided by continued repositioning of R3 to retract the specimen anteriorly and laterally into the right upper quadrant. The inferior pancreaticoduodenal artery can be identified and divided in this layer either with clips or Ligasure (Fig. 5e).

The final layer of the uncinate dissection consists of resection of the retroperitoneal tissue to the right and behind the SMA, which is accomplished with the LigaSure (Fig. 5f). Again, the key maneuver is to retract and elevate the specimen anteriorly to the right so that the remaining layer can be divided under direct visualization.

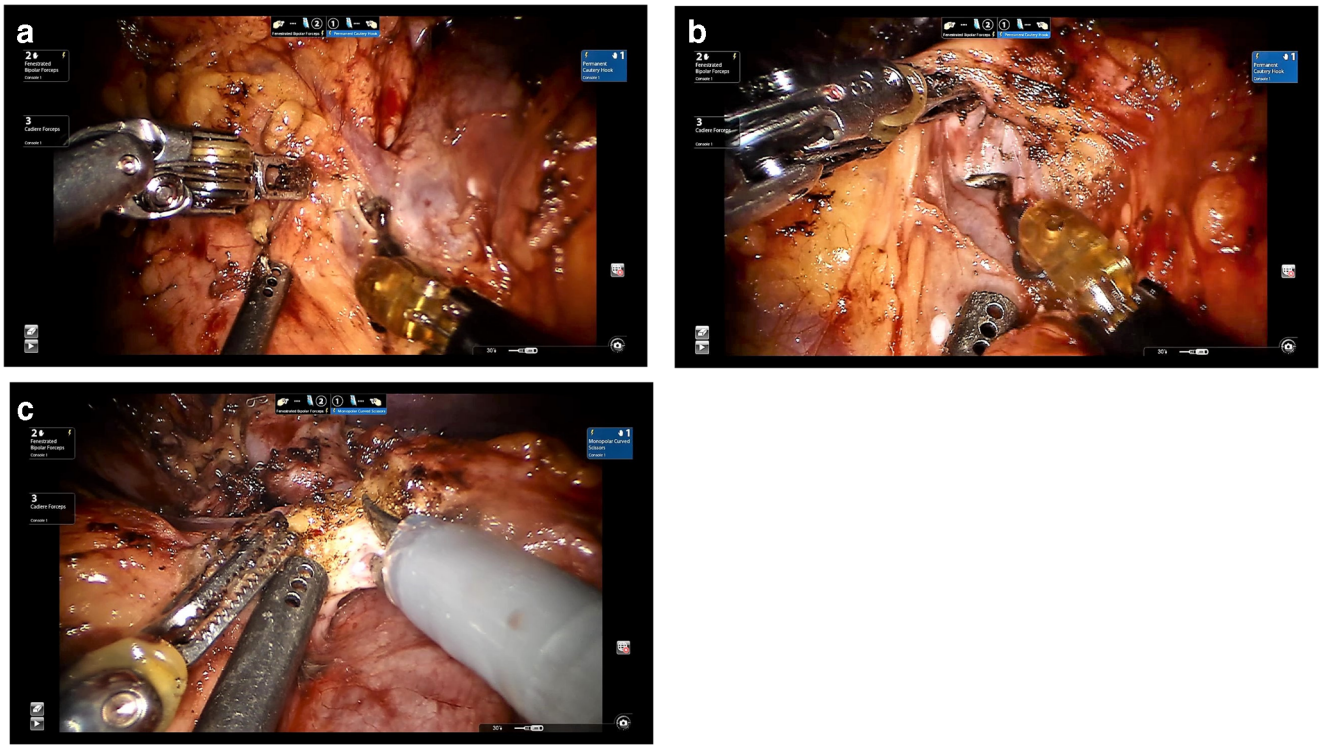

Fig. 4 Infrapancreatic dissection, creation of a retropancreatic tunnel, and division of the pancreas. The superior mesenteric vein is identified at the infrapancreatic border. The dissection proceeds inferiorly along this vein to identify the venous branches, including the gastrocolic trunk or trunk of Henle (**a**). Next, the retropancreatic tunnel is created. The closed fenestrated bipolar grasper (R2) is used as a spatula to lift the pancreas off the anterior surface of the superior mesenteric vein while the hook cautery separates the flimsy attachments from the vein to the pancreas (**b**). Once the tunnel is complete, the pancreatic parenchymal transection is done with "hot" robotic shears until the level of the pancreatic duct which is divided sharply (**c**). The bottom tine of the shears is in the lumen of the pancreatic duct

Specimen Extraction

A cholecystectomy is performed in standard fashion. The specimen is placed in a 15-mm endocatch retrieval bag. The LLQ 12 mm trocar site is extended to 4 cm, and the specimen is extracted. Once removed, a gel port (GelPoint Applied Medical, Rancho Santa Margarita, CA) is placed in the extraction site so that pneumoperitoneum can be maintained during the reconstruction. The 12-mm assistant trocar is placed through this gel port. The specimen is sent to pathology for frozen margin assessment as necessary.

Reconstruction Phase

The reconstruction phase proceeds in a standardized fashion using the instruments listed in Table 1.

Step 5: Pancreaticojejunostomy

A modified Blumgart technique is performed for pancreatic reconstruction. The anastomosis is performed in end-to-side fashion. First, the transected pancreatic neck is mobilized from the retroperitoneum for at least 1 cm to allow the jejunum to lay firmly opposed under the pancreas. The jejunal limb is brought up behind the root of the mesentery as a "neo-duodenum" and positioned with the antimesenteric border facing the transected edge of the pancreatic neck. Three, interrupted horizontal 2–0 silk mattress sutures (cut to 8 cm) are placed with full-thickness pancreas (starting from the anterior pancreatic surface to the posterior surface) and horizontally through the seromuscular layer of the jejunum and back again to the pancreas from posterior to anterior. The middle stitch is placed so that it straddles the pancreatic duct. A 4- or 5-French Hobbs ERCP stent (Hobbs Medical, Stafford Springs, CT) is placed in the pancreatic duct to prevent inadvertent narrowing. The sutures are tied so that the seromuscular bite of the jejunum is directly opposed to the posterior aspect of the pancreas (this is facilitated by previously mobilizing the pancreas off the retroperitoneum). While tying the sutures down, R3 keeps tension on the most superior suture, keeping the jejunum in direct apposition to the pancreas. The needles are left on these sutures and will be used for the anterior seromuscular layer. Easy mobility of the Hobbs stent is confirmed.

Next, the inner duct-to-mucosa layer is performed. An enterotomy is made using a single jaw of the robotic endoshears in the antimesenteric portion of the jejunum directly opposite the pancreatic duct. Interrupted sutures are placed circumferentially incorporating pancreatic duct and full-thickness jejunum using

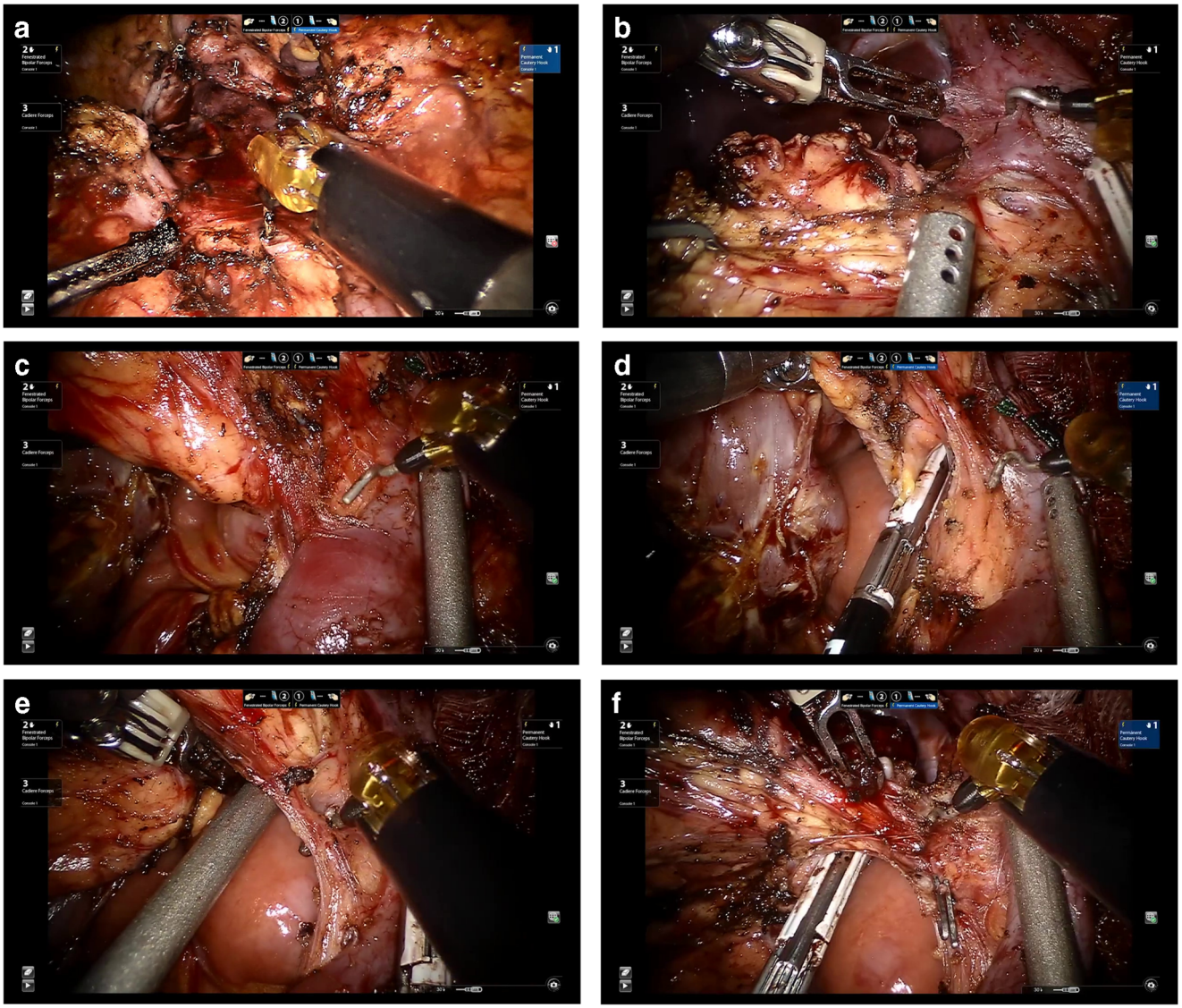

Fig. 5 Uncinate dissection. A meticulous dissection is paramount so that the entire uncinate process is removed with the specimen and oncologic margin maintained. The hook monopolar is used analogous to a right angle to carefully dissect and divide tissues of the uncinate margin (**a**). Smaller venous branches are carefully dissected and transected with the LigaSure. The superior pancreaticoduodenal vein (of Belcher) (**b**) is carefully dissected and typically divided with the LigaSure. The hook monopolar retracts the superior mesenteric vein medially, exposing the superior mesenteric artery (**c**). The SMA dissection proceeds in a methodical manner right along the SMA using the hook monopolar and LigaSure (**d**). The inferior pancreaticoduodenal artery is dissected at its base (**e**) and ligated with clips. The final remaining retroperitoneal attachments are divided with the LigaSure (**f**). Throughout the course of this dissection, exposure is optimized by retracting the specimen "up and out" with the fenestrated bipolar (R2) so that tissue can be divided right at the lateral border of the superior mesenteric artery

5–0 polydioxanone suture (Ethicon, Cincinnati, OH). Two to three posterior sutures are placed first. The Hobbs stent is now repositioned in the pancreatic duct and placed through the enterotomy into the lumen of the jejunum. The anterior sutures are now placed circumferentially to complete the inner layer. The anterior most sutures are not tied until all sutures have been placed so that each suture can be placed under direct visualization. The anterior, outer layer is now completed with the 2–0 silk sutures from the posterior layer. Again, seromuscular bites are taken and tied so that jejunum completely encompasses the transected edge of the pancreas (Fig. 6).

Step 6: Hepaticojejunostomy

The technique for our end-to-side hepaticojejunostomy depends on the size of the common bile/hepatic duct. For smaller sized (< 8 mm) or thin ducts, we perform this anastomosis with interrupted 5–0 polydioxanone or 5–0 polyglyconate suture and typically place a Hobbs stent across the anastomosis. For larger ducts, we prefer a running anastomosis using two 4–0 V-Loc 180 green sutures (Covidien-Medtronic, Minneapolis, MN). The common hepatic duct staple line is cut sharply with scissors to ensure bleeding. An enterotomy is

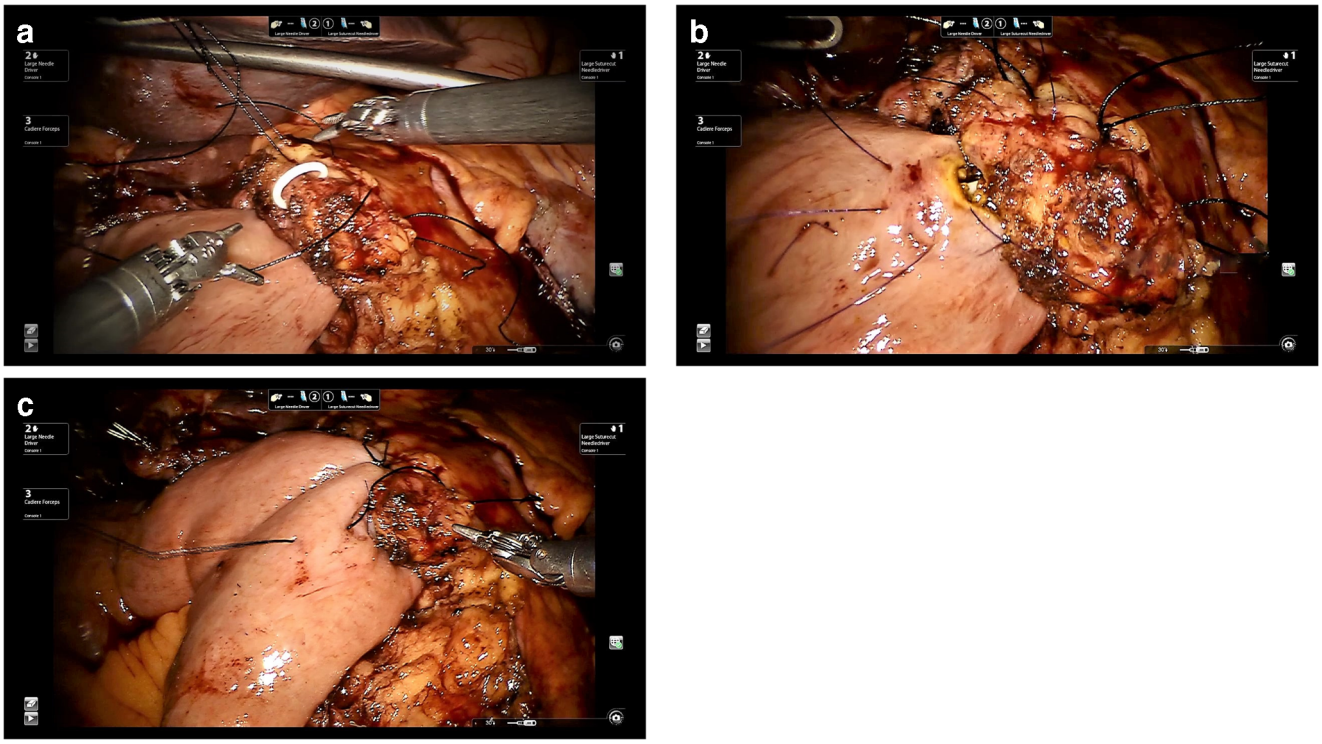

Fig. 6 Pancreaticojejunostomy. Three modified Blumgart style sutures are placed with full-thickness bites of the pancreas and seromuscular bites of the jejunum creating the posterior layer of the anastomosis (**a**). An enterotomy is made in the jejunum and an inner layer duct to mucosa anastomosis is performed (**b**). The final layer of the anastomosis is completed with additional Lembert sutures (**c**) that ensure the serosa of the jejunum is completely encompassing the transected edge of the pancreas

made in the jejunum slightly smaller than the diameter of the CBD/CHD, as the enterotomy tends to stretch with manipulation. The enterotomy is made approximately 10 cm distal to the PJ anastomosis and at a position where the bowel lays comfortably without any tension. The anastomosis is started on the right lateral edge of the CHD proceeding medially (to the left) with both V-loc sutures. Retraction and appropriate positioning of the anastomosis are provided by gentle traction on the anterior suture by R3. This allows excellent visualization of the posterior row which is completed first with a series of full-thickness bites on the CHD and jejunum. Next, the anterior layer is completed in similar fashion until the two sutures are overlapping. These two sutures are then tied together completing the hepaticojejunostomy (Fig. 7).

Step 7: Gastrojejunostomy

The initial step in this anastomosis involves marking the jejunum 30–40 cm distal to the hepaticojejunostomy with 2 sutures to allow identification of an afferent or efferent limb. The next step

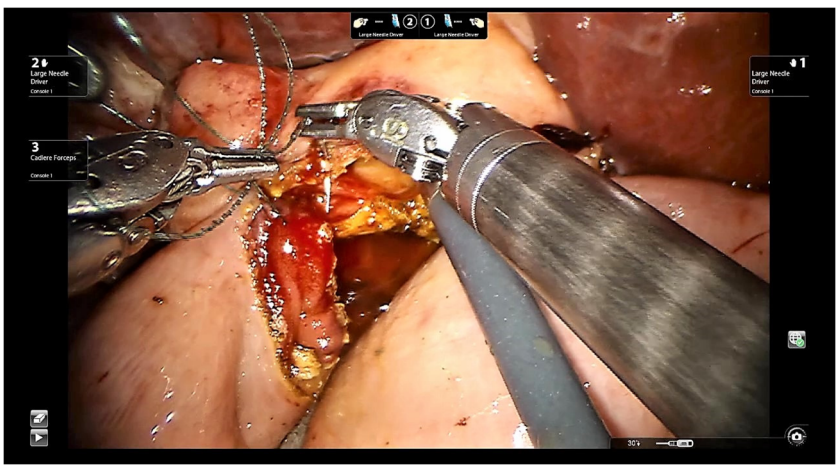

Fig. 7 Hepaticojejunostomy. For larger biliary ducts, a continuous running anastomosis is performed with two 4–0 V-Loc sutures. Both sutures are secured in the lateral portion of the anastomosis. The posterior layer is completed first. Exposure is aided by R3 who retracted the anterior V-Loc suture while completing the posterior layer. The console surgeon follows himself with the large needle drive in R2

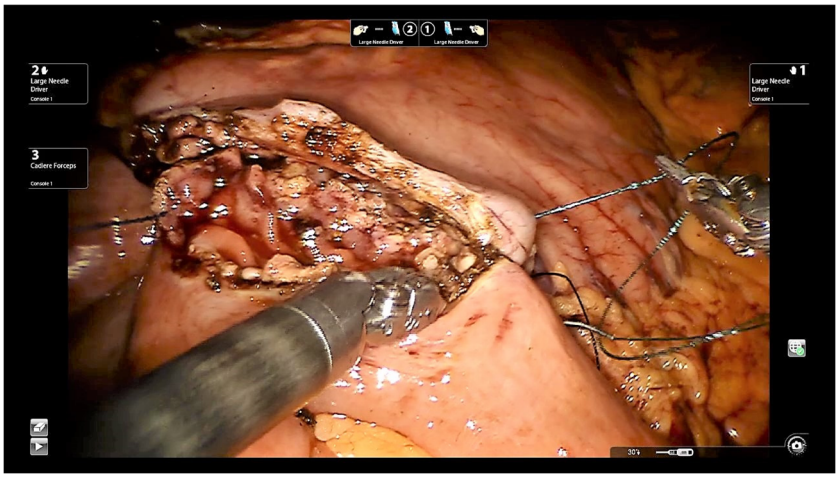

Fig. 8 Gastrojejunostomy. A two-layered, "robotic"-sewn anastomosis is performed. This figure depicts completion of the inner posterior row of the anastomosis with running 3–0 (9 in.) V-Loc suture. As the corner is completed, we transition from a simple continuous suture line to a running Connell stitch

requires a difficult robotic maneuver dependent on both the console surgeon and bedside assistant working in tandem. The transverse colon and its mesentery are retracted in a cephalad direction to find the base of the mesentery where the "neo-duodenum" passes through the defect of the divided ligament of Treitz. The excess jejunum is reduced through this defect. The 2 marking sutures are identified allowing appropriate orientation of the anastomosis. The jejunum is then brought up in antecolic fashion and an end-to-side hand-sewn, antecolic, isoperistaltic gastrojejunostomy is performed (Fig. 8).

The anastomosis is sewn in 2 layers. The posterior row is first completed with a series of interrupted, 2–0 silk Lembert sutures. R3 grasps and retracts the corner stitch placed along the lesser curve of the stomach providing optimal exposure. Approximately 4 cm of the gastric staple line is removed (from the greater curvature side heading towards the lesser curve) with "hot" robotic scissors, and an equidistant enterotomy is made in the jejunum. The interior layer is completed with two 3–0 V-Loc 180 green sutures (Covidien-Medtronic, Minneapolis, MN). Along the posterior aspect of the anastomosis, a simple continuous method is preferred while the anterior layer is completed with a running Connell stitch. The anterior, outer layer completes the anastomosis with a series of interrupted, 2–0 silk Lembert sutures. It is important to note that we have attempted to staple this anastomosis to decrease reconstruction time. However, an increase in delayed gastric emptying was anecdotally noted and we have reverted back to a hand-sewn technique.

Step 8: Drain Placement, Falciform Ligament Flap, Abdominal Closure

At the completion of the reconstruction, a 19-French blake drain is placed through the R3 trocar. This drain is placed anterior to the hepaticojejunostomy and pancreaticojejunostomy. A vascularized tissue flap is created from the divided round/falciform ligament and used to cover the transected GDA stump. The fascia of the 12-mm trocar and extraction sites are closed with #1 Polysorb interrupted sutures.

Post-Operative Management

Briefly, patients are managed on an enhanced recovery pathway (ERAS).[7] The nasogastric tube is removed shortly after skin closure or on the first postoperative day. Patients are transferred to a monitored surgical floor bed, and ICU admission is avoided in the vast majority of patients. Clear liquids can be started on POD 0 or 1. Diet is advanced as tolerated such that most patients are on a low residue diet by days 4–5. We practice early drain removal on POD 3–5 as guided by drain amylase levels and volume. Generally speaking, early drain removal is expected if drain fluid amylase on POD 1 (DFA1) is < 5000 and continues to decline by POD3. Somatostatin analogues, NSAIDS, and patient-controlled narcotic analgesia (PCA) are avoided while on ERAS protocol. Our targeted discharge is day 6 when feasible.

Conclusion

Robotic pancreaticoduodenectomy has been demonstrated to be a safe and feasible operation when performed by experienced surgeons. The University of Pittsburgh approach to RPD entails a systematic step-wise progression through operative steps. We have refined our technique over the course of a decade, identified the procedural learning curve, and demonstrated that our approach can be safely disseminated. Ultimately, good outcomes with RPD are dependent on careful patient selection, team approach, and a fundamental understanding of the principles of open pancreatic surgery.

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