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HOW I DO IT

How I Do It: Robotic Pancreaticoduodenectomy

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Introduction

Minimally invasive pancreaticoduodenectomy (Whipple procedure) has been described by several groups with favorable outcomes; however, this procedure has not been widely adopted for a variety of reasons.[1–7] The most significant barrier to its adoption is the technical skill level required to perform critical portions of the resection and reconstruction by using conventional laparoscopic instruments. We lack solid, scientific evidence (randomized controlled trials) to support the transition from an open to minimally invasive approach for Whipple procedures, and we have a long way to go as a surgical community in terms of validating this technique. Although many pancreatic surgeons cite this as a reason for not adopting a laparoscopic approach, it is plausible that they lack the technical training to perform critical steps of the procedure laparoscopically. From our perspective, we would not attempt a laparoscopic Whipple procedure, because we lack the technical capacity to perform many steps of the procedure with the same skill and precision that we have when performing an open pancreaticoduodenectomy (PD), using 2.5x loupes. This admission of humility, an attribute at variance among surgeons, led us to the use of robotics systems (daVinci Surgical System®, Intuitive Surgical, Sunnyvale, CA) in order to overcome the barriers of performing a minimally invasive Whipple procedure and my own limitations.

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Giulianotti pioneered the use of a robotic-assisted approach to perform PD, but this approach was not widely adopted due to concerns about the pancreaticojejunostomy reconstruction and pancreatic fistula rates.[8] Clearly, the group at the University of Pittsburg brought the robotic Whipple procedure into prime time and helped to propagate its adoption in the USA. Yet, even the early results from this group were met with skepticism, ridicule, and a general lack of enthusiasm.[9] The senior author (JBM) began using the robotic platform in 2006 and has performed over 800 hepatopancreatobiliary (HPB) procedures to date, but was admittedly skeptical and wary of performing robotic Whipple procedures due to the complexity, learning curve, lack of acceptable robotic instruments, and personal bias. This perception began to change with increasing experience and further development of the robotic platform. In 2012, our center began performing robotic Whipple procedures in selected patients, and we have since performed over 100 of these procedures.

Single-Surgeon Vs. Two-Surgeon Approach

Several differences exist between our approach and reports in the literature, in particular the technique published by the University of Pittsburgh.[10] The most notable and practical difference is the need for two experienced pancreatic surgeons acting as a team, one at the robotic console and another at the bedside.[10] Since 2006, our senior author (JBM) has performed most, if not all robotic hepatobiliary procedures without the assistance of a second surgeon at bedside. A highly dedicated and trained surgical technologist performs the tasks of passing sutures, exchanging instruments, suctioning, and, on occasion, stapling. The importance of having a dedicated surgical technologist and circulating nurse to support a successful

robotics program cannot be overstated. Although assistance from a second experienced pancreatic surgeon would have facilitated adoption of the robotic approach and shortened our learning curve, this was impractical from a logistical or financial standpoint. Many other centers with dedicated HPB programs likely encounter similar constraints. Incorporating a standardized robotic surgery curriculum has yet to be achieved in most general surgery residency programs, and a majority of residents who participate in our robotic HPB cases have no prior robotics experience. Due to the combination of inconsistent availability for complex robotic cases and a lack of prior robotics experience, residents are unable to provide reliable, significant benefit as bedside assistants.

The HPB program at Carolinas Medical Center has two clinical fellows, but they are not always available for robotics cases because of our high-volume caseload. When available for robotics procedures, fellows focus on acquiring skills by sitting at a second robotic console performing portions of the procedure appropriate for their skill level and experience. Given these factors, it was not surprising that review of our robotic PD procedures showed that a surgical technologist assisted in 75% of cases, a resident or fellow assisted in 25% of cases, and a second attending never assisted.

Pure Robotic Vs. Hybrid Approach

Many centers (University of Pittsburgh, Cleveland Clinic, Providence Portland Medical Center) have adopted and promoted a "Hybrid" approach to performing a robotic Whipple procedure, where a significant portion of the case, typically the resection phase, is done laparoscopically. The rationale for this varies from group to group, but includes the belief that a Whipple is a "multi-quadrant operation" and therefore more suited to the "free-handedness" of pure laparoscopy. Other explanations include the perception that straight laparoscopy is quicker than performing the resection with the robot. Earlier versions of the daVinci Surgical System® (standard, S, Si) platforms had their limitations, but several groups including our own were able to overcome the resultant ergonomic challenges. We chose to dock the robot directly over the head of the patient, approaching a Whipple as a "foregut/upper abdominal" operation and not a "multi-quadrant" procedure.

Many surgeons prefer to use the surgical energy device that they are familiar with. Prior to development and release of the wristed robotic bipolar vessel sealing device (EndoWrist® Vessel Sealer™) in 2012, many groups preferred to use laparoscopic devices such as bipolar devices (Ligasure™, Medtronic, and Enseal®, Ethicon) or an ultrasonic device such as the Harmonic scalpel or Sonicision™. Obviously, using a laparoscopic energy device such as one of these requires a second surgeon (either an attending, a fellow, or a very skilled surgical resident) to be at the bedside. To overcome the limitations of early instruments (monopolar scissors and fenestrated bipolar forceps), we adopted a "pure robotic" approach from the beginning, and with experience, we refined the steps of the procedures and ergonomic issues. However, since the introduction of the daVinci Xi® platform and the EndoWrist® Vessel Sealer™, it is likely that many centers will move towards a "pure robotic" and single-surgeon approach.

Preoperative Considerations and Patient Selection

Appropriate patient selection is critical to ensure patient safety. Early in the learning curve, we did not recommend robotic PD for patients with large malignant tumors (pancreatic or duodenal) or those abutting the portal vein/superior mesenteric vein (SMV). Ampullary carcinomas, distal cholangiocarcinomas, and smaller pancreatic malignancies are ideal cases, as they often result in dilated pancreatic and bile ducts making the reconstruction phase easier. Pancreatic endocrine tumors and cystic neoplasms are suitable as well, but those with relatively small ducts may require a more demanding reconstruction. The robotic platform should not be used for patients with large, borderline resectable and/or locally advanced tumors.

Patient-specific factors such as age, co-morbidities, body mass index (BMI), and multiple previous abdominal procedures play an important role and must be considered when evaluating patients for a robotic PD. Patients with congestive heart failure, pulmonary hypertension, or advanced COPD requiring oxygen should be excluded, even for surgeons beyond the learning curve. These patients will not tolerate pneumo-peritoneum for extended periods of time and may develop right-sided heart failure and severe metabolic acidosis intraoperatively. Patients with extremes of body weight, either morbidly obese, or extremely petite or cachectic body habitus should be excluded also. Excess visceral fat makes the identification of critical structures and the reconstruction more difficult. Extremely thin or petite patients present the opposite problem in that there is limited space on the abdominal wall, making placement of the robotic and assistant ports ergonomically challenging. As is true with many things in surgery, time and experience lead to increased comfort and confidence in one's robotic skills, at which time more difficult cases can be attempted.

Patient Positioning and Port Placement

The setup and port placement for a robotic PD vary slightly based whether the daVinci Xi® or the Si® system is used. Following the induction of general anesthesia, the patient is placed in a supine position with slight reverse Trendelenberg.

Two large-bore, peripheral intravenous lines and an arterial line are used for vascular access. Operative fluid management is guided by monitoring stroke volume variation (SVV) by using a Vigileo™ device (Edwards Lifesciences). A nasogastric tube and urinary catheter are placed and are typically removed on postoperative day one.

On the Si console, the bed is oriented at 90° to the anesthesia team with the robotic cart docking above the patient's head. The patient's right arm is tucked and the left arm is extended to provide vascular access. On the Xi console, the bed is oriented at 30–45° to the anesthesiologist and both arms are extended. The robotic cart is docked from the right side of the table. Equipment used for the operation is listed in Table 1.

We typically insufflate the abdominal cavity with a Veress needle introduced through a small infra-umbilical incision. A 12-mm port is then placed at this location and typically serves as the assistant port, as well as the specimen extraction site at the end of the procedure. In the cases of prior abdominal surgery or when adhesions are anticipated, a Veress needle is introduced in the left upper quadrant, and a 5-mm camera with optical-trocar is used to gain visualized access into the peritoneal cavity.

Table 1 Equipment for robotic pancreaticoduodenectomy

Items	Details (n = number required, if greater than 2)
Robotic system	Da Vinci™ Xi or Si system
Robotic instruments	30° camera
	Prograsp™
	Fenestrated Bipolar
	Monopolar scissors
	(2) Large and diamond needle drivers
	Bipolar vessel sealing device
	Large clip applier
	Robotic bulldog clamps
	Ultrasound probe
Ports	(2) 12-mm assistant trocars
	(3–4) 8-mm robotic trocars
Basic laparoscopic tray	Veress needle
	Suction—irrigation
	Needle drivers
	Stapling devices on standby
Suture	0 Vicryl suture
	4–0 V-lock
	4–0 Monocryl, cut to 12 cm
	5–0 Monocryl, cut to 12 cm
	6–0 Monocryl, cut to 12 cm
Specimen bags	Cook LapSac™—5 × 8, 8 × 10 (inches)
Drains	19 French Blake drain
Retractor	Nathanson retractor

The ideal port configuration for the Xi system is depicted is placement of the four robotic ports in nearly symmetrical positions along a horizontal line. Based on body habitus, port placement often requires adjustment. For patients who are extremely large, tall, or obese, the horizontal line must be moved more cephalad from the level of the umbilicus. The following depicts the general location and purpose of each arm going from the patient's right side to the left side:

- Arm 1—8-mm robotic port—right anterior axillary line. Fenestrated bipolar grasper.
- Arm 2—8-mm robotic port—right mid-clavicular line. Camera.
- Arm 3—8/12-mm robotic port—left mid-clavicular line. Monopolar scissors, vessel sealer, needle driver. This port may be upsized to introduce the robotic stapler as well.
- Arm 4—8-mm robotic port—left anterior axillary line. Progasp™ instrument.

Typically, the umbilical 12-mm port will serve as the assistant port; this is utilized for suctioning, exchanging suture material, and introducing the specimen retrieval bag. If the robotic stapler is not utilized, this port may be used for stapling also. An additional 5-mm port may be placed away from the remaining ports in a location ergonomically feasible for the assistant. This may be necessary for retraction or suctioning/irrigation. Following port placement, the patient is placed in a slight reverse-Trendelenburg position, perhaps 15–25°, and robotic arms connected to the ports. Instruments are then placed into the abdominal cavity and the procedure began.

Early in the learning curve for robotic-assisted PD, surgeons may contend with challenges when deciding optimal port placement and utilization. Many surgeons (including Giulianotti and Zeh) prefer to have two working robotic arms in their left hand (left side of the field) (personal communication, JBM). Over the course of our experience, we eventually settled on having two working arms on the right side of the field (surgeon's right hand) simply as a matter of standardization.

Resection Phase

Early Exposure

The round ligament, including the pro-peritoneal fat pad, is detached from the anterior abdominal wall and preserved upon its vascularized pedicle (attached to the liver at the umbilical fissure); this is used as flap coverage over the gastroduodenal artery stump and the pancreatic anastomosis. The fundus of the gallbladder is suspended to the right anterior abdominal wall with a 4–0 barbed monofilament suture (V-

Loc™) and serves to retract the liver and expose the porta hepatis (Fig. 1). This is a critical maneuver, as it frees up the surgeon's fourth arm for active assistance and participation throughout the procedure. If the gallbladder is absent due to a prior cholecystectomy, a Nathanson retractor is utilized for similar retraction of the liver. A 4 × 8 in. sponge is introduced into the abdomen to help maintain a dry field throughout the case, as well as to serve as a pad to minimize tissue trauma from the robotic instruments when retracting the tissue, particularly the colon and liver.

Kocher Maneuver

The greater curvature of the stomach is identified and elevated, following which the lesser sac is entered by using the robotic vessel sealer to open the gastro-colic ligament (Fig. 2). Arm #1 (fenestrated bipolar) and arm #4 (Prograsp™) are generally used throughout the procedure to retract and hold tissue while arm #3 (monopolar scissors and/or bipolar vessel sealer) performs most of the dissection (coagulating/sealing/cutting). The right gastroepiploic pedicle is followed down to the origin where it is either clipped with locking plastic clips (Hemolock™), or ligated with 3–0 silk ties and divided (Fig. 3). The dissection with the vessel sealer continues laterally across the anterior aspect of the pancreatic head and duodenum towards the hepatic flexure of the colon, which is then mobilized. A Kocher maneuver is performed to completely mobilize the second and third portions of the duodenum and the head of the pancreas away from the retroperitoneum (Fig. 4).

We try to mobilize the duodenum until we visualize the ligament of Treitz and the peritoneal window through to the proximal jejunum (although we do not yet bring the jejunum through this opening as many groups do). We have found that the camera positioned off-midline provides optimal visualization for this dissection. Attention is turned to opening the lesser omentum and the gastro-hepatic window, and the dissection is then carried out with the vessel sealer and the right gastric artery is sealed and divided. Any remaining attachments of the posterior aspect of the distal gastric antrum and proximal duodenum are mobilized with monopolar scissors, and the pylorus is positively identified. The robotic stapling device is introduced either at the umbilical trocar site or at arm #3, and the duodenum is divided approximately 2 cm distal to the pylorus (Fig. 5). Alternatively, the assistant may introduce a laparoscopic stapling device through the 12-mm umbilical port. The stomach is then placed into the left upper abdomen until the reconstruction phase.

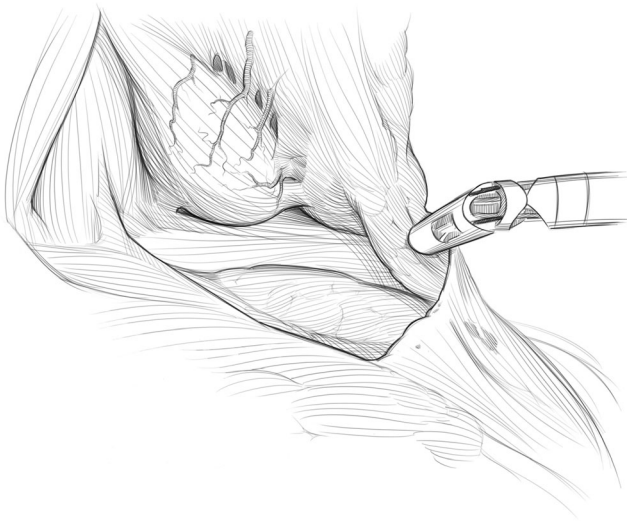

Fig. 2 Opening the lesser sac using the robotic vessel sealer

Porta Hepatis Exposure

A thorough ultrasound evaluation is performed by using the robotic "drop-in" probe (BK Medical, Denmark) to identify

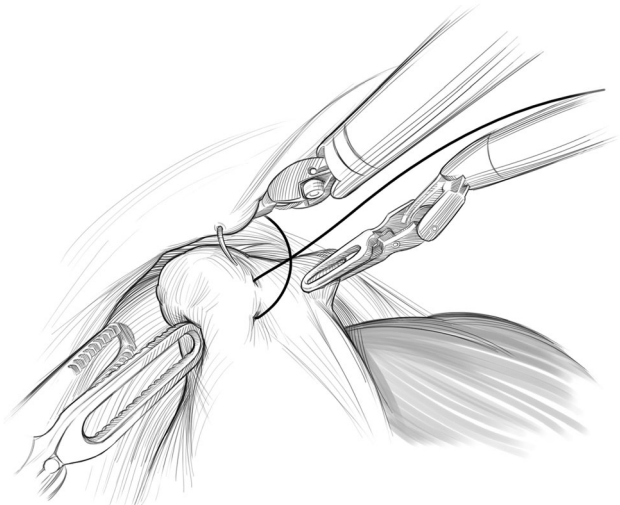

Fig. 1 Gallbladder stitch to provide exposure

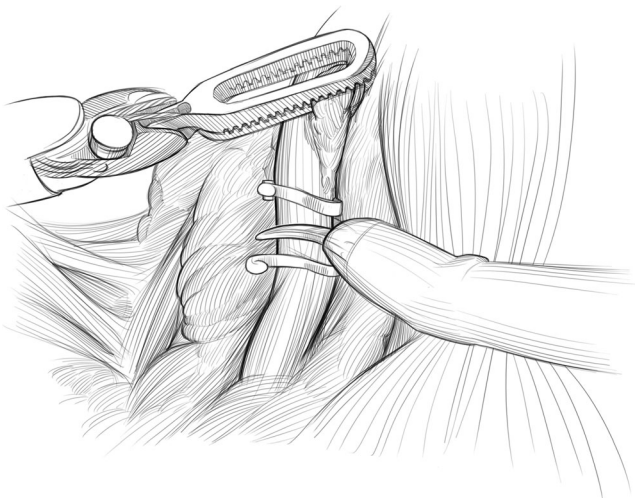

Fig. 3 Division of the right gastroepiploic artery

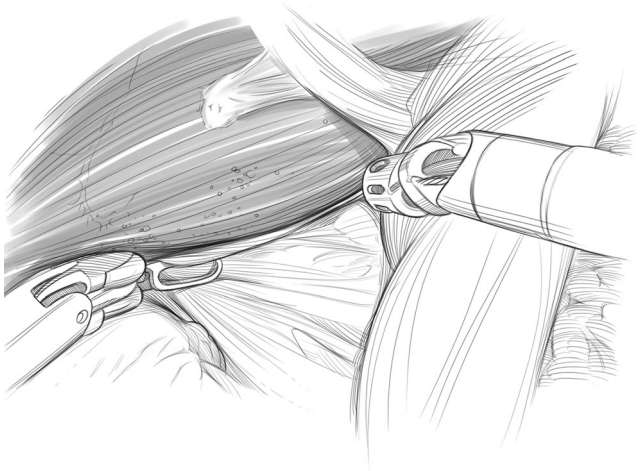

Fig. 4 Kocherization of the duodenum

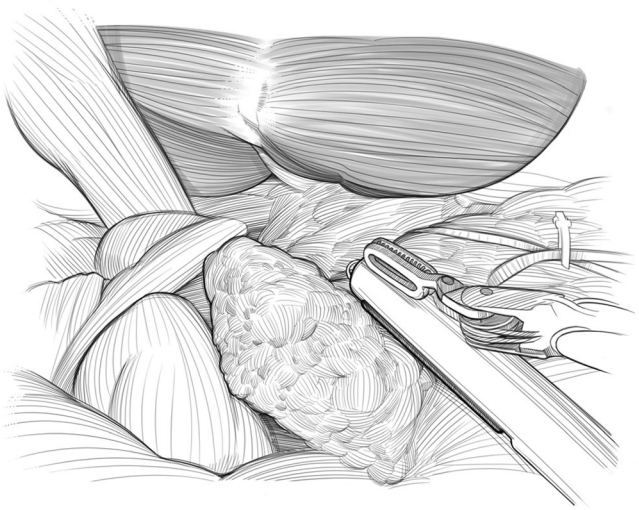

Fig. 6 Intraoperative ultrasound to identify critical vascular structures

the portal structures (Fig. 6). The location of the common hepatic artery (CHA), its left and right branches, and their relationship to the bile duct and portal vein are delineated. Identification of a replaced right hepatic artery originating from the superior mesenteric artery as well as "low lying" right hepatic artery is of particular importance. The gastroduodenal artery (GDA) must be identified with ultrasound and differentiated from a "low lying" right hepatic or common hepatic artery. The portal structures are now exposed by incising the peritoneum and dissected from the overlying fat using the monopolar scissors. The medial, central, and lateral/posterior portal lymph nodes (station 12) are commonly removed and sent separately for pathological examination as indicated. The common hepatic artery lymph node (station 8) is carefully resected at this point, further exposing the CHA and GDA. The GDA is ligated with 3–0 silk ties and secured with locking plastic clips, and then divided (Fig. 7). We have found this technique to be a very safe and reliable method and have not experienced any postoperative pseudoaneurysms or bleeding from the stump of the GDA. We discourage the use of vascular staplers for the transection, as the window is often not large enough to allow passage of the stapler. By dividing the GDA, the portal vein can be identified lying in a plane deeper than the common bile duct and proper hepatic artery, marking the superior aspect of the retropancreatic tunnel.

Control of Pancreatic Neck

The SMV is located by following the middle colic vessels proximally and confirmed with the aid of the ultrasound. Depending on the caliber of the venous branches, they are either ligated with 3–0 silk ties or controlled with the bipolar vessel sealer. An avascular plane/tunnel is developed between the pancreas and the SMV/portal vein by using the bipolar

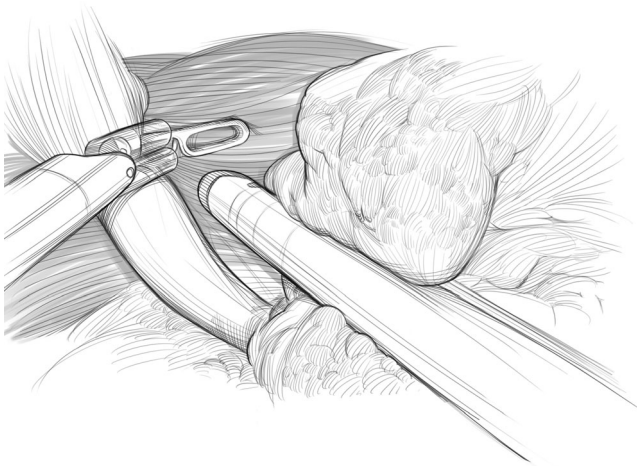

Fig. 5 Stapling the duodenum 2 cm distal to the pylorus

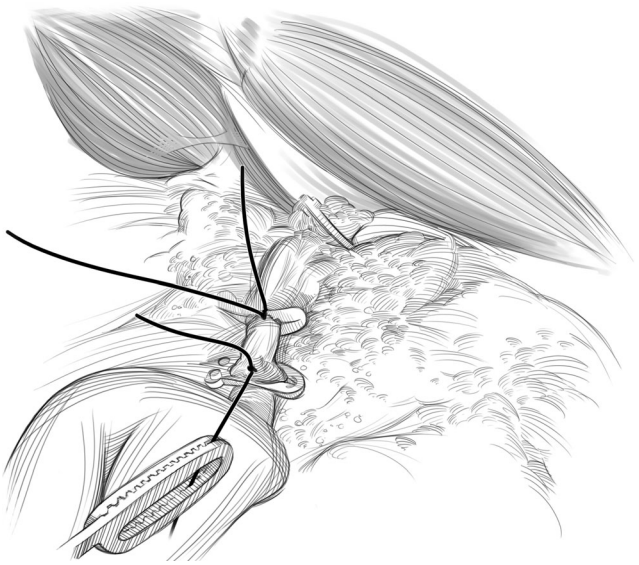

Fig. 7 Isolation and ligation of the gastroduodenal artery

vessel sealer in arm #3 to perform this delicate step (Fig. 8). An umbilical tape is then passed through the tunnel and retrieved at the superior border of pancreas for full control of the neck (Fig. 9).

Division of Ligament of Treitz and Proximal Jejunum

This step may be the most ergonomically challenging of the procedure because the ports are oriented towards the upper abdomen. We developed three different methods to address this issue.

Method #1: This was our initial technique and is similar to many groups performing robotic Whipple procedures. It involved pulling the distal duodenum and proximal jejunum through the retro-mesenteric window created during the Kocher maneuver (termed "over-Kocherization") until the ligament of Treitz and proximal jejunum can be stapled and divided from the right side. Typically, the jejunum (biliary-pancreatic limb) is then left in this retro-mesenteric, "native tunnel" position.

Method #2: This approach mirrors our open surgical technique, where we elevate the greater omentum and transverse colon to expose the ligament of Treitz and proximal jejunum. The jejunum is divided with the robotic stapler (Fig. 10) and the mesentery is split lengthwise along the proximal jejunum towards the ligament of Treitz (Fig. 11). The biliary-pancreatic limb is then brought up to the right upper quadrant through the bare area in the right side of the transverse colon mesentery. This technique is often useful in patients who do not have significant intra-abdominal obesity or a large greater omentum, and is our preferred method (all things being equal).

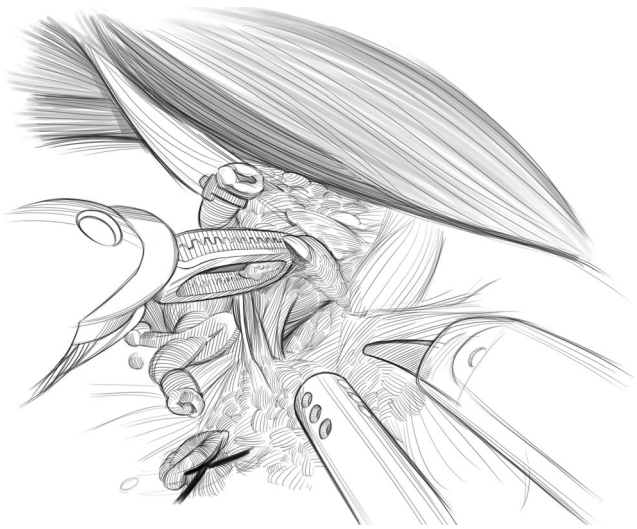

Fig. 8 Dissection along the inferior border of the pancreas

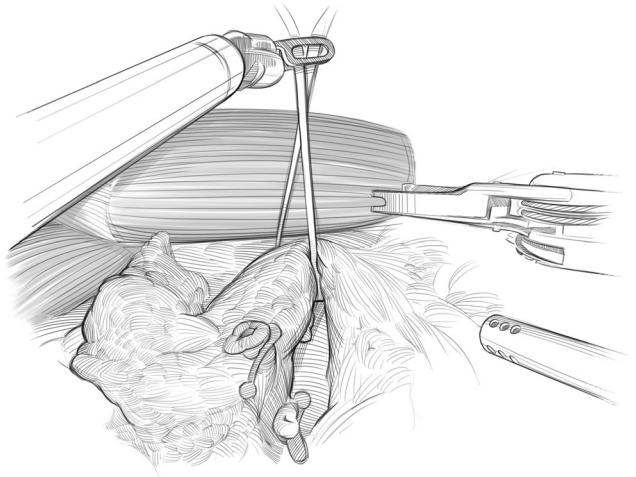

Fig. 9 Isolation of the pancreatic neck and placement of umbilical tape

Method #3: This technique was developed by necessity in patients with a large omentum that is fixed in the pelvis as a result of prior surgery. A window is made in the transverse colon mesentery on the (patient's) left side of the mesenteric vessels, below the inferior border of the body of the pancreas. (This is the same opening made inadvertently by surgeons at times during a distal pancreatectomy, and allows almost immediate identification of the distal duodenum and the ligament of Treitz). Once the proximal jejunum is identified, it may be looped up into the lesser sac in a position above transverse colon (retro-colic position) where it may be stapled and the mesentery divided with the vessel sealer. This is a portion of the procedure that is often overlooked and underestimated, requiring particular skill and finesse on the part of the surgeon.

Division of the Pancreatic Neck and Uncinate Process

After pulling the proximal jejunum through to the right upper quadrant, the neck of the pancreas is divided using the monopolar scissors coupled with saline irrigation to help minimize charring and desiccation of the tissue. Closer to the central portion of the pancreas near the pancreatic duct, it is important to use sharp transection to minimize the risk of structuring the pancreatic duct. There are typically a few small arterial bleeding points on either side of the transected pancreas that require hemostatic control with either electrocautery or suture ligation using a 5–0 monofilament suture. We have

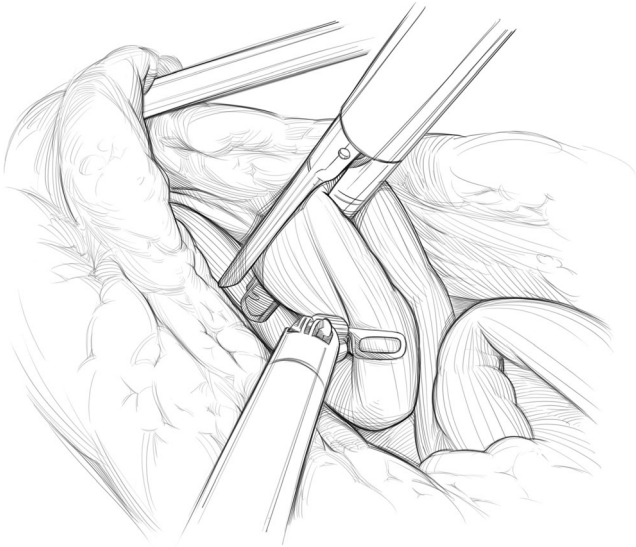

Fig. 10 Stapling of the jejunum

found it unnecessary to place large sutures in the pancreas prior to transection, as has been popularized by many techniques. The head of the pancreas and duodenum are now retracted laterally, towards the right side of the abdomen, and attention is turned to mobilizing the uncinate process off of the SMV (Fig. 12). The inferior-most aspect of the tissue is actually not truly pancreatic tissue, but rather "mesopancreas." This includes lymphatics, and often the "first jejunal" venous tributaries, which can be controlled with either the vessel sealer or clips.

Ultrasound should again be performed to determine the precise location of the SMA, and the vessel sealer may now be used to begin mobilizing the uncinate process away from this critical vascular structure. Larger branches such as the inferior pancreaticoduodenal artery (IPDA) should be identified with the ultrasound and preemptively clipped and divided. Following dissection of the uncinate process and transection of the uncinate tissue, one encounters the posterior duodenal lymph nodes (station 13). These should be included with the specimen and can be a particularly annoying source of bleeding if not handled appropriately. This area can also be treacherous, as a replaced right hepatic artery or posterior-coursing, anomalous right hepatic artery may be located. These should be identified pre-operatively with good cross-sectional imaging and intraoperative ultrasound.

Division of Bile Duct and Gallbladder

If not done previously, the peritoneum overlying the upper porta hepatis is opened, and the cystic duct and artery are identified, ligated, and divided. The common hepatic duct is circumferentially dissected out and ideally divided just above the insertion of the cystic duct. A small bulldog clamp may be introduced to occlude the common hepatic duct to prevent bile spillage in the operative field. The gallbladder is left in-situ to provide retraction of the liver until the reconstruction is completed, and is sent as a separate specimen.

Handling of the Specimen

The specimens are placed within a large fabric specimen sack (LapSac™ Cook Medical). It is helpful to roll the edges of the pouch inwards to facilitate specimen placement. The assistant can use a laparoscopic instrument to grasp the lower border of the pouch. Once the specimen is placed within the pouch, it is synched down with a Weck™ Lock and placed away from the operative field. The specimen is removed at the conclusion of the case, unless frozen section margins need to be assessed prior to reconstruction. We have abandoned the practice of routing frozen section analysis of all margins (pancreatic neck, uncinate, biliary) in cases of pancreatic adenocarcinoma, and do so on a selected, case-by-case basis.

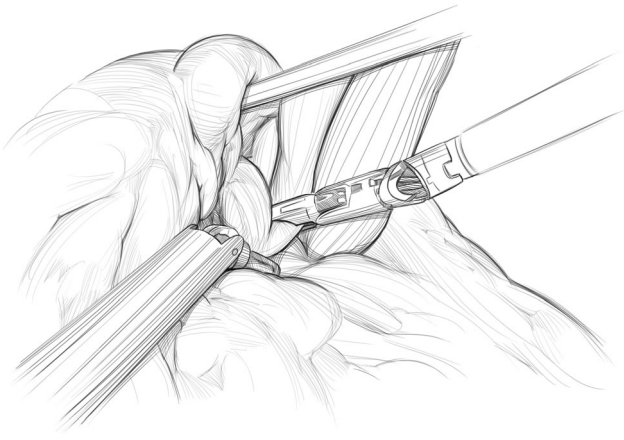

Fig. 11 Division of the jejunal mesentery along its length using the vessel sealer

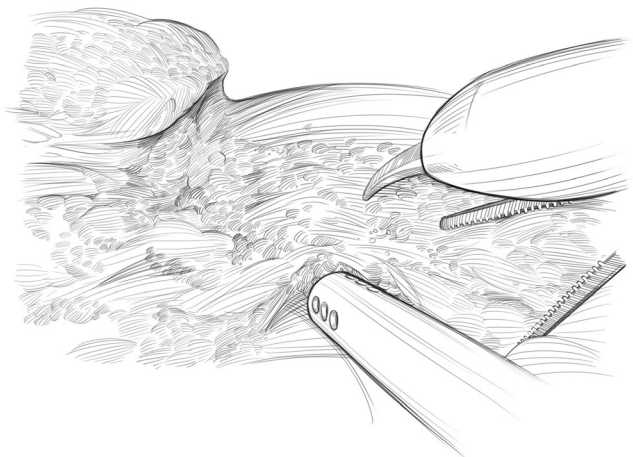

Fig. 12 Uncinate dissection

Reconstructive Phase

The proximal end of the free limb of jejunum is brought through an opening in the transverse mesocolon, "the bare area," to the right of the middle colic vessels. (Our preferred method, #2 described above). This limb of intestine should comfortably reach the right upper quadrant without undue tension in order to create the pancreatic and biliary anastomoses. In patients with particularly thick or shortened small bowel mesentery, it may be necessary to remove additional length of jejunum in order to eliminate the tension. There are occasions where our preferred method is not feasible, and the jejunum must be brought up through the retro-mesenteric, native tunnel. As a matter of principle, when performing the procedure robotically, we try to mirror the open technique at our institution as much as possible, including the pancreatic, biliary, and gastro/duodenal anastomosis.

Pancreaticojejunostomy

The pancreaticojejunostomy is performed as a two-layer, end to side anastomosis. The posterior layer is created by approximating the capsule of the pancreas and the sero-muscular layer of the jejunum in running fashion using a 4–0 monofilament, absorbable suture (Monocryl, Ethicon, Cincinnati) (Fig. 13). Using the monopolar scissors, a small enterotomy is made in the jejunum to match the approximate diameter of the pancreatic duct. The latter step is an especially delicate one. Using interrupted 6–0 monofilament sutures, a duct to mucosa anastomosis is then performed, placing from 4 to 8 sutures depending on the diameter of the duct (Fig. 14). Over time, we have refined our technique and currently use either a 5Fr or 7Fr pancreatic duct stent. The anterior wall is completed using another running 4–0 absorbable monofilament suture, similar to the posterior layer. The previously harvested round ligament flap is wrapped posteriorly around the anastomosis, simultaneously covering the GDA stump.

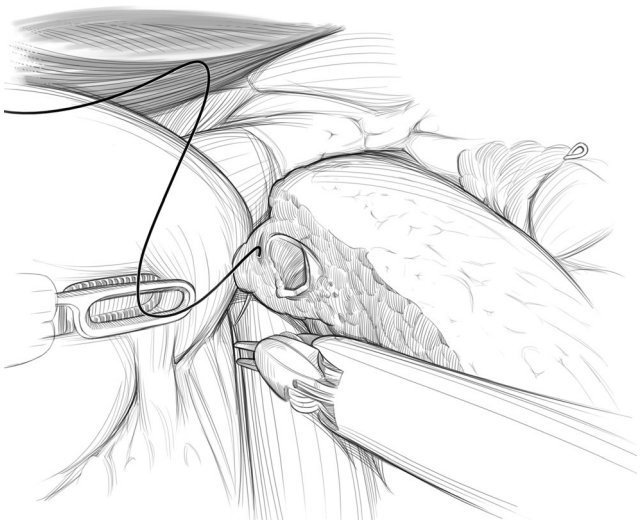

Fig. 13 Creation of the posterior layer of the pancreaticojejunostomy

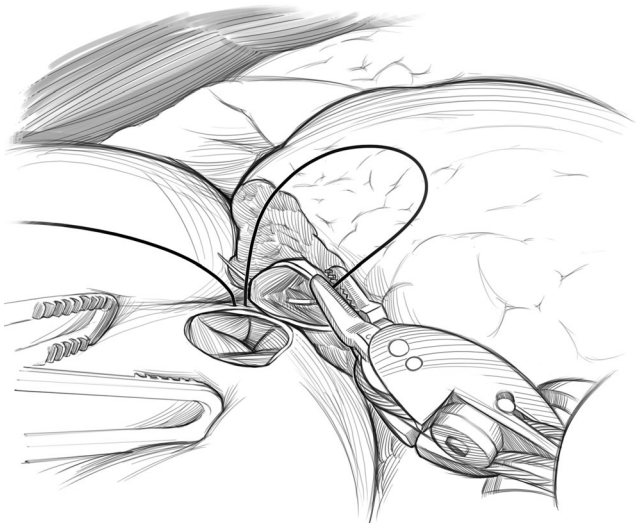

Fig. 14 Duct to mucosa pancreaticojejunostomy using interrupted 6–0 monofilament suture

Hepaticojejunostomy

The biliary reconstruction is performed approximately 10–15 cm downstream from the pancreatic anastomosis, and the specific technique depends largely upon the diameter and thickness of the bile duct. Relatively small ducts, under 8–10 mm or so are reconstructed using interrupted 5–0 monofilament absorbable sutures (Monocryl, Ethicon). Larger, thicker ducts such as patients who have had metal biliary stents placed or chronic biliary obstruction are reconstructed using running sutures, including a 4–0 monofilament, barbed, absorbable suture (V-loc suture, Medtronic) (Fig. 15). We do not stent the biliary anastomosis.

Gastro/Duodenojejunostomy

The jejunum is allowed to descend through the transverse colon mesentery, following which a loop is brought up anterior to the transverse colon in antecolic fashion to create the duodenojejunostomy. This mirrors our open technique of pyloric-preservation. The anastomosis is performed in single-layer fashion, using three separate running sutures. The initial suture of a 4–0 monofilament barbed suture is used to suspend the weight of the jejunum to the posterior aspect of the distal gastric running antrum, in order to decrease tension on the anastomosis. The staple line on the duodenum is removed using the monopolar scissors, and a linear enterotomy is created on the jejunum matching the duodenal opening. The posterior wall of this anastomosis is now performed using a second running 4–0 suture in a running, "baseball stitch" fashion (Fig. 16). The

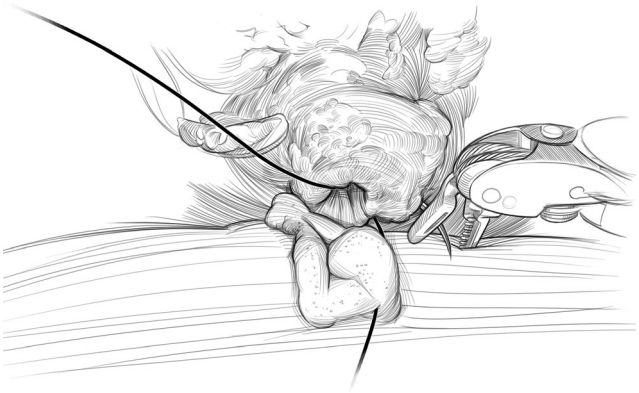

Fig. 15 Bile duct anastomosis

anterior wall is completed using the third 4–0 suture, employing a running, inverting Lembert style technique.

Specimen Extraction and Completion

Following completion of the anastomosis, the gallbladder resection is completed, allowing the liver to drop down. The round ligament vascularized pedicel flap is passed posterior to the pancreaticojejunostomy and then flipped up to cover the anterior aspect of the anastomosis. This maneuver serves to completely wrap the anastomosis and serves as a tissue buffer covering the portal vein and the stump of the gastroduodenal artery. The abdomen is irrigated with saline and final inspection for hemostasis is performed. A single-fluted closed suction drain is placed in close proximity to the pancreatic and biliary anastomosis. The specimens are now extracted from the umbilical 12-mm assistant port site, which is enlarged inferiorly, approximately 3 to 4 cm.

Outcomes

There are currently no randomized control trials comparing outcomes between robotic-assisted and laparoscopic or open PD. Existing single or multi-institutional studies are retrospective in nature, some using propensity score matching to compare specific outcomes, such as clinically relevant pancreatic leak rates between robotic-assisted and open approaches. A large, multi-center study compared the outcomes of 211 patients from two high-volume robotic PD centers and 817 patients from six high-volume open PD centers.[9] Median operative times were approximately 75 min more with the robotic approach although the estimated blood loss was 181 mL lower on average. Rates of clinically relevant grade B/C pancreatic fistulas did not differ between robotic or open approach. There was no difference between either approach with respect to short-term oncologic outcomes, such as lymph node harvest and margins. Postoperative outcomes, such as 90-day mortality, 90-day readmission rate, length of stay, and wound infection rate, were similar.

The University of Pittsburgh published a propensity score-matched analysis to determine the effect of the robotic or open approach on the incidence of clinically relevant grade B/C pancreatic fistulas.[11] The study showed non-inferiority of the robotic to the open approach in terms of clinically relevant pancreatic fistula development. Patients undergoing a robotic-assisted PD had a postoperative pancreatic fistula rate of 6.6% compared to the 11.2% fistula rate for patients undergoing an open PD. There were no differences in 90-day mortality, 30-day readmission rates, or overall complication rate between the two groups.[11]

Outcomes have been examined in certain specific patient populations, such as those with a high BMI.[12] Obese patients classified as those with BMI > 30 kg/m^2 were found to have higher rates of grade B/C fistulas after PD. Interestingly, obese patients who underwent a robotic PD were found to have a lower clinically relevant fistula rate of 13% compared to a 28% fistula rate in those that had an open PD. Another interesting finding was that morbidly obese patients had a 19% wound infection rate with the robotic approach compared to 44% in those morbidly obese patients who had an open PD. There were no differences in the mortality or Clavien 3 or greater morbidity rates between robotic and open approaches for obese patients. However, it must be noted that all the patients in this retrospective study underwent robotic PDs performed by surgeons who had surpassed a learning curve of greater than 80 cases.[12]

A NSQIP study comparing 30-day outcomes between laparoscopic and robotic PDs reported that there was no difference in the 30-day morbidity or mortality between either approach.[13] However, this study reported that conversion rates to an open procedure were higher for patients undergoing

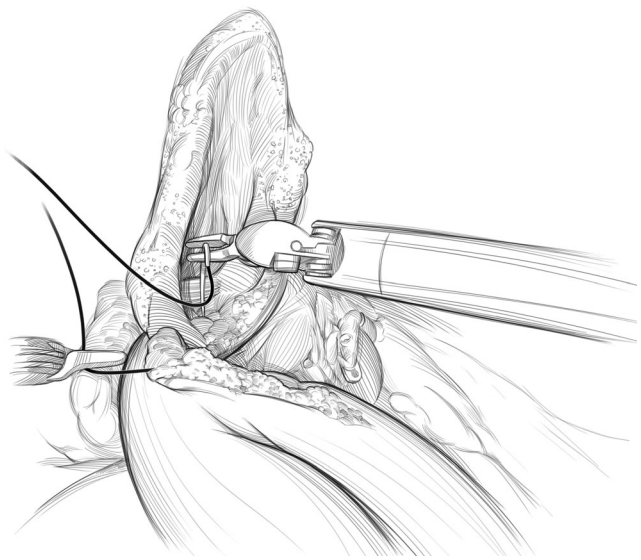

Fig. 16 Duodenojejunostomy

laparoscopic PD. Robotic PD was converted to an open procedure 11.3% of the time compared to a conversion rate of 26% for the laparoscopic approach.[13]

Over a 5-year period (2012–2017), the senior author (JBM) performed 89 robotic Whipple procedures. Initial retrospective review of our single-surgeon experience with robotic PD at Carolinas Medical Center between 2012 and 2014 showed longer operative times of approximately 136 min when compared with our open PD cohort. However, as noted by Boone et al., a statistically significant decrease in operative times was seen with increasing case numbers.[14] Our median operative time decreased by 68 min during 2015–2017 when compared to previous years.

As expected, estimated blood loss was approximately 400 mL lower with the robotic approach during the initial time period. This decreased further by approximately 200 mL between 2015 and 2017. The rate of clinically relevant grade B/C pancreatic fistulas was 10.2% with a 30-day mortality rate of 2.2%. Overall, with the robotic approach, patients in our cohort had lower wound infection rates and shorter intensive care unit and hospital length of stays. This translated to similar overall costs between the robotic and open approach.

Summary

We present our approach for a robotic-assisted PD, which, admittedly has some significant differences to other prominent groups who have previously published their techniques. Although our technique has evolved, we believe that the refinements and modifications that have been introduced over time have resulted in shorter procedural times and improved patient outcomes.

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Amit V Sastry—design; interpretation; drafting manuscript; manuscript revision; approval of final version.

Dionisios Vrochides—concept; design; interpretation; manuscript revision; approval of final version.

John B Martinie—concept; design; interpretation; drafting manuscript; approval of final version.

Compliance with Ethical Standards

This study has received ethical approval by the Atrium Health Institutional Review Board as it satisfies requirements of 45 CFR 46 110, category #5. This was a retrospective study and informed consent was not required by the IRB.

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