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Technical Detail for Robotic-Assisted Pancreaticoduodenectomy

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Corresponding Author:	Amer Zureikat University of Pittsburgh Medical Center Pittsburgh, Pa UNITED STATES
Corresponding Author's Institution:	University of Pittsburgh Medical Center
Corresponding Author E-Mail:	zureikatah@upmc.edu
Order of Authors:	Alex C. Kim, M.D., Ph.D.
	Rebecca Rist
	Amer H Zureikat
Additional Information:	
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Editorial Comments

- I have changed the protocol to imperative tense throughout. Please review. Also, we cannot have paragraphs of text in the protocol section. I have made substeps instead. Please review.
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TITLE:

Technical Detail for Robot Assisted Pancreaticoduodenectomy

AUTHORS AND AFFILIATIONS:

Alex C. Kim[1], Rebecca C. Rist[1], Amer H. Zureikat[1]

[1]Department of Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

Corresponding Author:

Amer H. Zureikat (zureikatah@upmc.edu)

Email Addresses of Co-authors:

Alex C. Kim (kimac2@upmc.edu)

Rebecca C. Rist (ristr@upmc.edu)

KEYWORDS:

pancreatic surgery, minimally invasive surgery, robotic pancreaticoduodenectomy, RPD, robotic Whipple, robot-assisted surgery, RAS

SUMMARY:

The following manuscript details a stepwise approach to the robot-assisted pancreaticoduodenectomy performed at the University of Pittsburgh Medical Center.

ABSTRACT:

Since its first report in 2003, robotic pancreaticoduodenectomy (RPD) has gained popularity among pancreatic surgeons. Inherent advantages of the robotic platform, including three-dimensional vision, wristed instruments, and improved ergonomics, allow the surgeon to recapitulate the principles of open pancreatoduodenectomy allowing safe oncologic dissection, hemostasis, and meticulous reconstruction. Over the course of the past decade, significant strides have been achieved in outlining the safety, feasibility, and learning curve of the robotic Whipple. When performed by high volume pancreatic surgeons experienced in RPD, recent comparative effectiveness studies show potential advantages compared to the open technique, including reductions in hospital stay and morbidity. National data also show reductions in conversion rates compared to its laparoscopic counterpart. Although long-term oncologic data are still needed, short-term oncologic surrogates of margin resection and lymph node harvest suggest no compromise in oncologic outcomes. As pancreatic surgeons increasingly integrate robotics into their practice, proficiency-based training and credentialing will be necessary for the safe application and dissemination of RPD. Here, we provide the detailed steps of a robotic pancreaticoduodenectomy performed at the University of Pittsburgh Medical Center.

INTRODUCTION:

Pancreaticoduodenectomy (PD) is a complex operation that combines a challenging resection and a meticolous reconstruction. During its early inception, the traditional open approach was frought with high complication rates and a mortality rate approaching 25%. In the last three

decades, improvements in the surgical technique and perioperative care led to corresponding improvements in outcomes, with a reduction in mortality to less than 5%, especially at high volume centers[1–3]. Despite this, morbidity remains substantial. With advancements in surgical technology, minimally invasive surgical approaches through laparoscopy or robot-assisted surgery have emerged in an effort to curb this morbidity. Since its first report in 2003, interest in robotic pancreaticoduodenectomy (RPD) has grown by pancreatic surgeons[4,5]. Inherent advantages of the robotic platform, including three-dimensional (3D) vision, wristed instruments, and improved ergonomics, allow the surgeon to recapitulate principles of open PD (OPD) in a minimally invasive manner, including safe oncologic dissection, hemostasis, and meticulous reconstruction[4,6–10]. The goal of this manuscript is to provide the detailed steps of an RPD performed at the University of Pittsburgh Medical Center (UPMC)[11–13].

In the presented case study, a 42-year-old female with a previous history of intraductal papillary mucinous neoplasm (IPMN), initially presented with acute pancreatitis. Computed tomography (CT) of the abdomen revealed a 3.3 cm pancreatic head lesion with associated dilatation of the main pancreatic duct (**Figure 1A**,**B**), with a mixed type IPMN. Endoscopic ultrasound (EUS) confirmed the existence of an irregular, heterogenous cyst measuring 3.1 x 2.0 cm in the pancreatic head with mixed solid and cystic components and main PD duct dilation (**Figure 1C**). EUS cytology revealed the presence of atypical cells with no high-risk molecular mutations[14,15]. Biochemical workup including serum tumor markers were normal, with CA19-9 12 U/mL. Based on the Fukuoka criteria, this patient was recommended to have a PD and was deemed a suitable candidate for the robotic approach[16].

PROTOCOL:

This protocol follows the guidelines of the University of Pittsburg Medical Center human research ethics comittee (Institutional Review Board: PRO15040497)

1. Preoperative workup and selection

1.1. Check the triphasic CT scan (i.e., chest, abdomen, and pelvis with the primary imaging modality) to evaluate the extent of disease, rule out metastasis, and delineate aberrant or anomalous arterial vasculature.

1.2. Perform EUS and endoscopic retrograde cholangiopancreatography (ERCP) for the tissue diagnosis and biliary decompression, especially in the setting of the planned neoadjuvant chemotherapy for pancreatic cancer.

1.3. Check for the relative contraindications for RPD, including tumor involvement of the portal vein or SMV that necessitates a vascular resection and reconstruction, previous upper gastrointestinal reconstruction (e.g., gastric bypass), extensive adhesions, and BMI > 40.

2. Anesthesia

2.1. Consider all patients for the institutional enhanced recovery pathway after the surgery (ERAS) with multimodal analgesia, including regional nerve blockade or intrathecal morphine, gabapentin, nonsteroidal analgesia, minimization of narcotic administration, and intraoperative goal-directed fluid resuscitation[13].

2.2. Perform deep venous thrombosis prophylaxis with a subcutaneous unfractionated heparin 5000 U injection and pneumatic placement of sequential compression devices prior to the induction. Place an arterial line (central lines are not routinely placed).

2.3. Administer preoperative antibiotics, typically with 4.5 g piperacillin/tazobactam, or 1–2 g ceftriaxone and 500 mg metronidazole, or 150 mg clindamycin and 500 mg metronidazole, 1 h prior to incision.

2.4. Place oral gastric tube following intubation and remove after the case.

3. Patient positioning

3.1. Position the patient in a supine position on a split-leg table with the right arm tucked and secured to the table with pressure points padded (**Figure 2**).

3.2. Turn the operating table approximately 45˚ counterclockwise from anesthesia to accommodate the docking of the Si robot. Dock the Xi robot from the side, as this does not require the turning of the table.

4. Placement of ports and liver retractor

4.1. Establish the access to the intraabdominal cavity by utilizing a 5 mm optical separator trocar in the left upper quadrant, midclavicular line, one hand's breadth to the left of the umbilicus. Advance the laparoscope into the abdominal cavity and perform a full inspection to rule out any peritoneal or visceral metastasis.

4.2. Upsize this trocar to an 8 mm robotic cannula (Arm 1 or A1).

4.2.1. Place the remaining ports as depicted in **Figure 3**. Place two 8 mm robotic ports in the right upper abdomen: place arm 2 (A2) in the midclavicular line, place arm 3 (A3) in the subcoastal anterior axillary line.

4.2.2. Place a 12 mm camera port approximately 2 cm above and to the right of the umbilicus.

4.2.3. Place a 12 mm laparoscopic assistant port in the left lower quadrant/midclavicular line, one hand's breadth lower than the upper robotic ports and between A1 and the camera port.

4.2.4. Place a 5 mm laparoscopic assistant port is placed in the right lower quadrant, one hand's breadth lower than the upper robotic ports and between A2 and the camera port.

4.2.5. Finally, place a 5 mm laparoscopic port for a liver retractor in the left anterior axillary line. Place the liver retractor to the leftmost lateral port. Ensure that the liver retractor is able to retract the gall bladder and lifts the liver superiorly during the entirety of the resection period.

4.3. Place the patient in a steep reverse Trendelenburg position and dock the robot.

5. Resection phase

5.1. The robotic instruments

5.1.1. Ensure that A1 is equipped with hook cautery.

5.1.2. Ensure A2 is equipped with fenestrated bipolar forceps.

5.1.3. Ensure A3 is equipped with bowel grasping forceps (robotic instrument catalog number 470049).

NOTE: The bedside assistant (two lower assistant ports) utilizes any combination of laparoscopic atraumatic grasper, laparoscopic suction irrigator, and laparoscopic blunt tip vessel sealing device.

5.2. Entrance into the lesser sac and mobilization of the right colon

5.2.1. Grasp the anterior stomach and retract anteriorly and cephalad with A3.

5.2.2. Gain access into the lesser sac through the greater omentum below the gastroepiploic pedicle using A1 and A2. The assistant provides a gentle caudal counter-retraction.

5.2.3. Carry out the dissection along the greater curvature towards the pylorus. Ensure that the right colon flexure is fully mobilized off the duodenum.

5.2.4. Preserve the gastroepiploic pedicle and do not transect it at this point.

5.3. Kocherization of the duodenum and dissection of the ligament of Treitz (LOT)

5.3.1. Grasp the lateral fibers of the duodenum with A2 and transect with A1. The bedside assistant provides gentle medial counter-retraction of the duodenum.

5.3.2. Carry out the mobilization of the duodenum including its 3rd and 4th portions to the LOT.

NOTE: Dynamic anterior and cranial retraction of the duodenum with A3 is key to an excellent exposure of the LOT. Extensive kocherization allows for the full visualization of the inferior vena cava, insertion of the left renal vein, and aorta.

5.3.3. Perform the complete release of LOT with A1 to allow for the exposure of the proximal jejunum.

5.3.4. Extract the proximal jejunum through the LOT defect into the right supracolic upper quadrant (creation of the neoduodenum for the reconstruction phase).

5.4. Transection of the proximal jejunum

5.4.1. Measure the jejunum approximately 10 cm distal to the LOT.

5.4.2. Transect the jejunum 10 cm distal to the duodenojejunal junction using a 60 mm curved tip vascular linear stapler.

5.5. Linearization of the duodenum

5.5.1. Divide the mesentery of the proximal jejunum by a sequential ligation with a blunt tip vessel-sealing device up to the uncinate process.

5.5.2. Take extreme care during this dissection because hemorrhage from the branches of the SMV can occur due to the lateral traction of the duodenum.

5.6. Transection of the distal stomach

5.6.1. Take care to not injure an aberrant or accessory left hepatic artery if present. While A1 and A2 are utilized for the dissection, use A3 to further retract the liver anteriorly.

NOTE: A3 releases the duodenum and stretches the pars flaccida underneath. The lesser sac is accessed superiorly through the pars flaccida.

5.6.2. Mark the stomach with a 60 mm thick linear stapler 5 cm proximal to the pylorus to perform the classic PD.

5.6.3. Ligate the right gastroepiploic vessels (RGEV) with the blunt tip vessel-sealing device at the corresponding area of the greater curvature. Transect the stomatch utilizing a thick linear stapler.

5.7. Dissection and transection of right gastric vessels

5.7.1. Ligate the right gastric artery (RGA) with laparoscopic titanium vascular 10 mm clips close to where it branches off from the proper hepatic artery.

5.7.2. Transect the RGA with the blunt tip of the vessel sealing device at the lesser curvature 5 cm proximal to the pylorus.

5.8. Dissection and excision of common hepatic artery lymph node

5.8.1. Use A3 to grasp the distal gastric staple line and retract the specimen laterally and inferiorly, putting the common hepatic artery (CHA) and the porta hepatis under tension. Continue the dissection through the superior border of the pancreas and into the porta hepatis. Use the energy function of both A1 and A2 to completely dissect the CHA, gastroduodenal artery (GDA), and RGA.

5.8.2. Excise the CHA lymph node, which allows complete exposure of the CHA. Retrieve it with a 10 mm laparoscopic specimen retrieval bag and send the specimen for permanent pathologic analysis. This allows for the full visualization of the GDA.

5.9. Dissection and transection of GDA

5.9.1. Identify the GDA where it branches off from the CHA. Utilize the robotic hook to fully circumferentially dissect the GDA.

5.9.2. Pass a vessel loop around the GDA. A test clamp may be used with confirmation of flow using visualization from a robotic ultrasound (US) probe. Transect the GDA with a vascular stapler. The proximal stump is reinforced with laparoscopic titanium vascular 10 mm clips.

5.9.3. Now identify the portal vein (PV) above the neck of the pancreas.

5.10. Dissection and transection of the common bile duct (CBD)

5.10.1. Dissect the PV for 2–3 cm in a cephalad direction. Identify the plane between the CBD and the PV and develop it posteriorly. Dissect all intervening portal lymph nodes and reflect towards the specimen.

5.10.2. Encircle the CBD/CHD with a vessel loop. If present, take care not to injure a replaced right hepatic artery behind the CBD/CHD.

5.10.3. Transect the CBD/CHD with a 60 mm curved tip vascular linear stapler above the level of the biliary stent (if present) to minimize bile spillage and field contamination.

5.11. Dissection of SMV and creation of the superior tunnel

5.11.1. Dissect the lateral border of the portal vein using the robotic hook cautery.

5.11.2. Ligate the superior pancreaticoduodenal artery, which is often encountered during this procedure, utilizing the assistance of the blunt tip vessel sealing device. Continue the superior-

to-inferior dissection of the portal vein up to the superior border of the pancreas. This dissection allows for the exposure of the superior tunnel.

5.12. Dissection of the SMV and creation of the inferior tunnel

5.12.1. Using A3, grasp and retract the distal gastric staple line laterally and cephalad to stretch the gastroepiploic vein (GEV) as it enters the anterior SMV. Open the fatty tissue near the pancreatic inferior border using electrocautery in A1. The SMV is now visible.

5.12.2. Identify the gastrocolic trunk (Trunk of Henle). Occasionally, there can be a right branch of the middle colic vein (RBMCV) that drains into the trunk. If present, dissect and transect it with the blunt tip vessel sealing device. Trace the GEV to its insertion into the SMV and transect with the blunt tip vessel sealing device.

5.12.3. Dissect off the SMV from the inferior border of the pancreas and create a retropancreatic neck tunnel between the pancreas and SMV/PV.

5.13. Pancreatic parenchymal transection and placement of pancreatic duct (PD) stent

5.13.1. Using A3, now retract the specimen laterally to stretch the pancreatic neck. Control the superior and inferior longitudinal pancreatic arteries with the bipolar in A2, thus obviating the need for transfixation sutures.

5.13.2. Transect the pancreatic neck using monopolar curved scissors in A1 and take care to identify the main duct. The assistant provides anterior lift of the pancreas off the SMV using suction during the parenchymal transection.

5.13.3. Transect the main PD with monopolar curved scissors without electrocautery.

5.13.4. Place a 4–5 Fr pancreatic duct stent into the PD to ensure its identification. Transect the remaining pancreatic parenchyma using an electrocautery.

5.14. Dissection and division of the uncinate process

NOTE: This portion of the resection requires slow and meticulous dissection, because significant hemorrhage may occur in absence of operative precision. The key to head and uncinate dissection during this phase is the judicious use of A3, which provides superior and lateral retraction of the specimen.

5.14.1. Keep A3 dynamic during the resection and make frequent readjustments to ensure appropriate retraction in an ‘up and out’ orientation, analgous to a surgeon’s left hand in an open PD.

5.14.2. Ensure that all three layers are dissected while performing the uncinate process dissection.

5.14.2.1. Transect the first layer using a hook cautery in A1. The first layer consists of filamentous fibers between the SMV/PV and the head/uncinate. This layer is devoid of any major vascular branches.

5.14.2.2. Use a combination of the hook cautery in A1 and the assistant's blunt tip vessel sealing device for dissection and ligation of the second layer. The second layer consists of the first jejunal vein (coursing lateral then posterior to the SMA), the Vein of Belcher/posterosuperior pancreaticoduodenal vein (entering the PV at the superior portion of the head/uncinate) and small uncinate branches. Preserve the first jejunal vein.

5.14.2.3. Transect with a curved tip vascular stapler if it requires ligation due to tumor involvement. Transect the Vein of Belcher with the blunt tip vessel sealing device. Take extreme care during this dissection, because avulsion of any of those vessels will result in significant hemorrhage.

5.14.2.4. Identify the third layer, which is the SMA/retroperitoneal margin. Rotate the SMV/PV medially with the help of an assistant (using the 12 mm right lower quadrant laparscopic port), while continuing to pull the specimen up and out with A3. Visualize the SMA and dissect along the plane of Leriche utilizing the robotic hook in A1 and the assistant's blunt tip vessel sealing device (in the left lower quadrant 5 mm laparoscopic port). Identify the inferior PDA in this layer and take with the blunt tip vessel sealing device or between clips.

5.14.3. Following the completion of the uncinate dissection, perform the cholecystectomy.

5.15. Specimen extraction

5.15.1. Place the specimen into a laparoscopic 15 mm specimen extraction pouch through a 4 cm extraction incision in the left midclavicular line.

5.15.2. Place the multi-instrument laparoscopic advanced access gel port through the extraction site and initiate the reconstruction phase. Reinsert a 12 mm laparoscopic port through the gel port to facilitate the passage of sutures for reconstruction.

6. Reconstruction phase

6.1. Main robotic instruments

6.1.1. Ensure A1 is armed with a large dual function needle driver with suture scissors. This is frequently switched to monopolar curved scissors to perform an enterotomy/gastrotomy.

6.1.2. Ensure A2 is equipped with a large needle driver.

6.1.3. Ensure A3 is equipped with fenestrated bipolar forceps used to grasp the pancreaticobiliary limb and steady it in the right upper quadrant during the pancreaticojejunostomy and hepaticojejunostomy.

6.2. Pancreaticojejunostomy (PJ)

6.2.1. Perform the PJ in a two-layer, end to side, duct to mucosa method, with the modified Blumgart technique. Use A3 to grab the previously placed sutures to provide cranial retraction and exposure.

6.2.2. Place 2–0 silk transpancreatic horizontal mattress sutures to secure the pancreas parenchyma to the jejunum. Place three sutures: one above, one below, and one straddling the pancreatic duct. Tie all three sutures, and keep the needles on the sutures. Take care when tying the middle suture, which straddles the main PD, to avoid accidental ductal ligation.

6.2.3. Use a 4–5 Fr pancreatic duct stent to interrogate the patency of the duct. Switch A1 to the monopolar scissors that are utilized to perform the enterotomy. Then replace again with the large dual function needle driver with suture scissors.

6.2.4. Use interrupted 5–0 polydioxanone (PDS) sutures to approximate the jejunal mucosa to the pancreatic duct. Place a minimum of six sutures (two posterior, two lateral, and two anterior). More sutures can be placed if larger ducts are encountered.

6.2.5. Reuse the same three silk needles, previously used for the posterior layer, for the anterior layer of the PJ as well. Place them in a simple fashion in the jejunum and tie these to complete the anastomosis.

6.3. Hepaticojejunostomy (HJ)

6.3.1. Perform the HJ approximately 10 cm distal to the PJ, and in a single layer either in interrupted (5–0 PDS) or running (4–0 barbed sutures) fashion.

6.3.2. Use A1 with monopolar curved scissors to transect the CBD staple line and to perform the enterotomy. Replace A1 and A2 with a large dual function needle driver with suture scissors and large needle driver, respectively.

6.3.3. Perform the anastomosis using 5–0 poly(p-dioxanone) sutures in an interrupted fashion for ducts measuring <1 cm. For larger ducts, use two running 4–0 barbed sutures in a single layer, continuous fashion. Place both sutures at the 9 o'clock position and ensure that they run in opposite directions towards the 3 o'clock position. Tie the sutures after the completion of the anastomosis.

6.3.4. For interrupted anastomosis, first place and tie the posterior sutures. For ducts measuring <1 cm, employ 4–5 Fr stents to keep the patency of anastomosis. Next, place additional 5–0 PDS sutures to complete the anterior anastomosis. Once all the sutures are in place, tie the sutures and complete the anastomosis.

6.4. Gastrojejunostomy (GJ)

NOTE: The GJ is a handsewn, antecolic, end-to-side, isoperistaltic anastomosis.

6.4.1. Place two 3–0 silk marking stitches on the jejunum approximately 40–60 cm distal to the HJ to mark the bowel as proximal and distal, respectively, denoting afferent and efferent limbs of the jejunum. Replace A1 and A2 with bowel grasping forceps #1 and #2 (robotic instrument catalog number 470093 and 470049, respectively). The laparoscopic assistant reflects the omentum and mesocolon cephalad, which allows the surgeon to locate the neoduodenum.

6.4.2. Reduce the distal jejunum and place it back into the infracolic compartment. Identify the two marking stitches, and bring the jejunum in an antecolic, isoperistaltic fashion up to the stomach.

6.4.3. Replace A1 and A2 with a large dual function needle driver with suture scissors and a large needle driver, respectively. Place an interrupted outer layer with 2–0 silk sutures. Hold the most cephalad suture by A3 and use it as a retraction suture. Replace A1 with monopolar curved scissors.

6.4.4. Transect 6 cm of the gastric staple line with scissors electrocautery and perform a corresponding jejunal enterotomy. Perform the inner layer using two 3–0 barbed sutures in running Connell fashion. Place the interrupted outer layer, 2–0 silk sutures to complete the second layer.

6.5. Drain placement

6.5.1. Following the completion of the anastomosis, place a 19 Fr round channel drain posterior to the HJ and anterior to the PJ. A falciform ligament flap may be utilized to cover the GDA stump.

6.5.2. Remove the instruments and liver retractor, and undock the robot.

6.5.3. Close the fascia and incisions in layers.

REPRESENTATIVE RESULTS:

In the representative case, the total operative time was 225 min with an estimated blood loss (EBL) of 50 mL (**Table 1**). The patient was admitted to the surgical ward. Her postoperative course followed the UPMC institutional ERAS pathway. We routinely assess JP amylase at POD#1 and #3 to assess for pancreatic fistula and practice early drain removal on POD 3-5 when possible. The

patient's JP amylase levels were 403 U/L and 68 U/L, respectively. Therefore, the drain was removed on POD#3. The patient was discharged on POD#6.

Pathologic analysis of the specimen revealed invasive moderately-differentiated adenocarcinoma (0.2 cm) centered in the pancreatic head and arising in a branch-duct IPMN (3.7 cm) with extensive high-grade dysplasia with no positive lymph nodes in any of the 32 resected. There was no evidence of lymphatic, venous, or perineural invasion. Final AJCC 8th edition stage was pT1aN0M0. The patient was recommended to undergo adjuvant chemotherapy with FOLFIRINOX as per the PRODIGE 24 trial[17]. The patient completed the therapy and remains without any evidence of disease.

FIGURE AND TABLE LEGENDS:

Figure 1: Preoperative diagnostic imaging. (**A**) and (**B**) IPMN in the head of the pancreas with associated main pancreatic ductal dilatation. (**C**) EUS demonstrating heterogenous pancreatic head mass with mixed solid and cystic components.

Figure 2: Patient positioning and anesthesia setup. Patient is positioned supine in a split leg table with all pressure points padded. Patient table is positioned to accommodate for both the surgical robot and the anesthesia devices. This figure was reproduced with permission from Intuitive Surgical, Inc.

Figure 3: Port placement. Purple 8 mm ports (robotic arms [A] 1–3), green 12 mm umbilical port (camera port), green 12 mm left lower quadrant port (assistant), red 5 mm right lower quadrant port (assistant), left lateral 5 mm port (liver retractor). This figure was adapted with permission from Springer, Journal of Gastrointestinal Surgery, Performing the Difficult Cholecystectomy Using Combined Endoscopic and Robotic Techniques: How I Do It. Magge, D. et al[26].

Table 1: Comparison of the represented case with national data[9].

DISCUSSION:

With advances in the surgical technology, laparoscopic and robot-assisted surgeries are being increasingly used in gastrointestinal and hepatobiliary procedures. Conventional laparoscopy is associated with benefits over open surgery for many procedures. However, inherent limitations such as decreased surgical dexterity, suboptimal ergonomics, lack of wristed instruments, and 2-D visualization, have limited its dissemination to complex gastrointestinal operations such as PD.

Contrary to laparoscopy, the robotic platform allows for the minimally invasive operations to be performed under 3D vision, with enhanced dexterity and the use of articulating (wristed) instruments. The Si is an older system and is the basis for which the authors have performed the vast majority of RPDs. The main inherent advantage of the older model (e.g., Si) is the use of a larger (12 mm) robotic camera with improved definition over the 8 mm camera (e.g., Xi). However, in this case both the newer and the older versions are used interchangeably for RPD. Regardless of the model, RAS allows for the open PD principles to be adhered to when performing the minimally invasive surgery. Despite concerns over oncologic outcomes, morbidity, cost, and

training, several single, multi-institutional, and national series have demonstrated the safety and feasibility of RPD[5,7,8,15]. More recent data demonstrate that RPD can be associated with improvements in morbidity and length of stay compared to the open approach and reductions in conversion compared to the laparoscopic approach[9,18–21].

Based on our experience at UPMC, several factors are needed for successful implementation of RPD. These include an institutional commitment to program success with necessary training and mentorship, prior surgeon experience in open pancreatic surgery, use of two staff surgeons to navigate through the initial learning, availability of a large case volume (2–4 cases/month), prospective assessment of perioperative outcomes, and dedicated operating room staff.

Data from our experience suggests the learning curve of RPD to be approximately 80 cases[22]. Notably, this is quite similar to the learning curve of OPD as demonstrated by three other reports.[1,23,24] Reductions in EBL and operative conversions occur early (20 cases), while a decrease in clinically relevant pancreatic fistula rate occurs after 40 cases. Operative time, a surrogate of procedural efficiency, is optimized after 80 cases. Following identification of our learning curve, we established a training program with the objective of disseminating safe robotic pancreatectomy. This stepwise mastery-based curriculum includes five main components: 1) mastery of the console, 2) virtual reality, 3) innanimate and bio-tissue drills, 4) live operative proctoring, and 5) continuous quality improvement and assurance[11,13,25].

There are a few technical considerations for RPD that warrant emphasis. During the operation, communication between the bedside and console surgeons is paramount. Both surgeons must adhere to the same operative plan and anticipate each other's maneuvers. In the resection phase, A3 plays a key role in retraction of the specimen to allow for optimal exposure. There are three critical parts in the operation that can result in significant intraoperative hemorrhage: 1) dissection of LOT and linearization of the duodenum after the proximal jejunal transection, 2) dissection of the inferior pancreatic border to begin the retropancreatic tunnel, and 3) dissection of the uncinate process. These phases demand extreme caution and warrant a thorough knowledge of operative anatomy. Control of hemorrhage may be challenging and requires a fascile ability to suture with 4–0 and 5–0 monoflament sutures, an experienced bedside assistant to control suction, and the ability to perform a quick and safe open conversion if bleeding is not controlled. In the reconstruction phase, A3 similarly plays a major role, since it is often utilized to grasp and retract previously placed sutures in a cranial direction to allow for countertension when placing sutures.

In conclusion, we provide a stepwise description of our RPD technique. Our technique follows principles of open PD, while allowing safe and oncologically sound application of a minimally invasive approach to this complex operation.

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Figure

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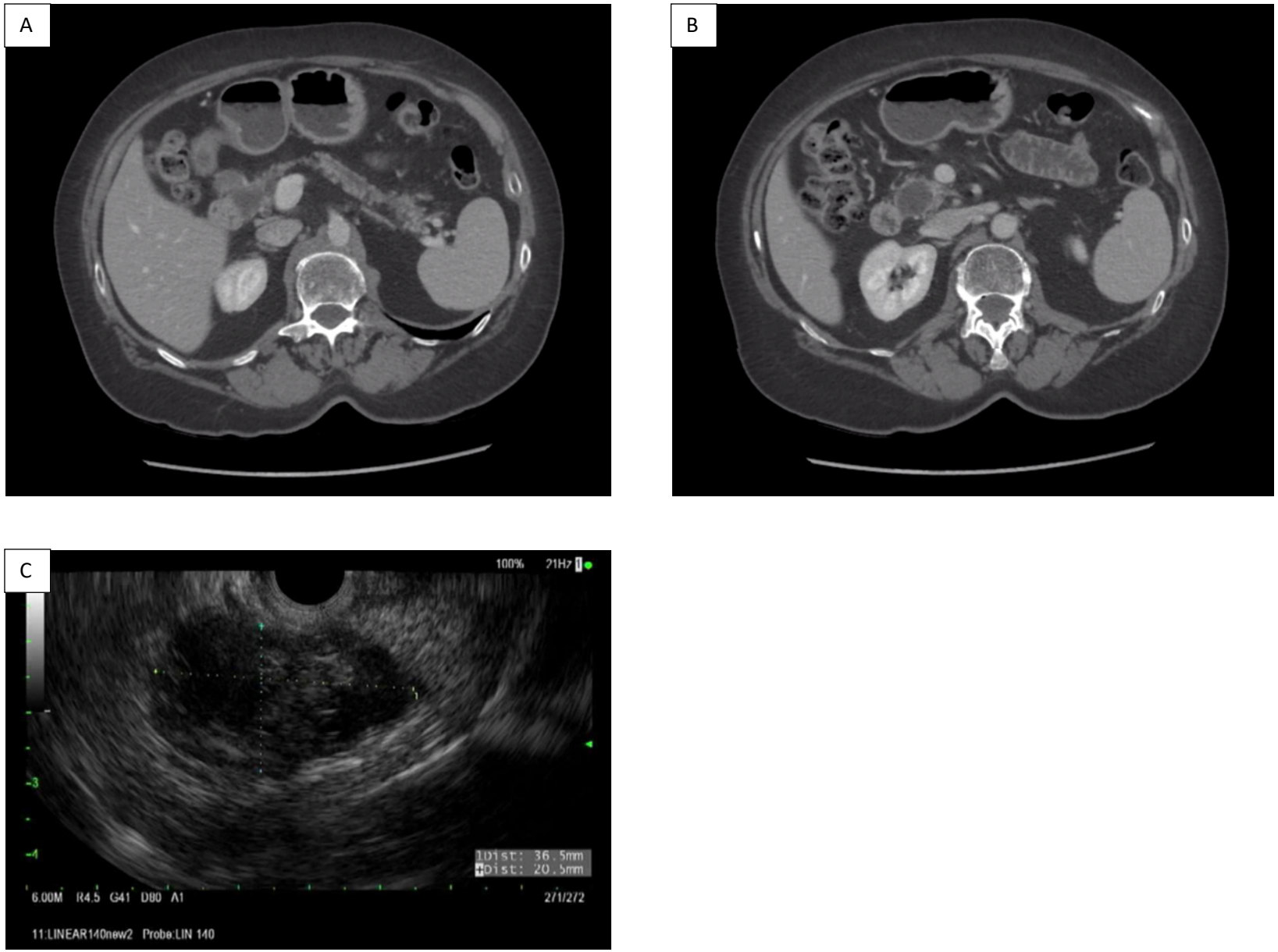

Revised Figure 2

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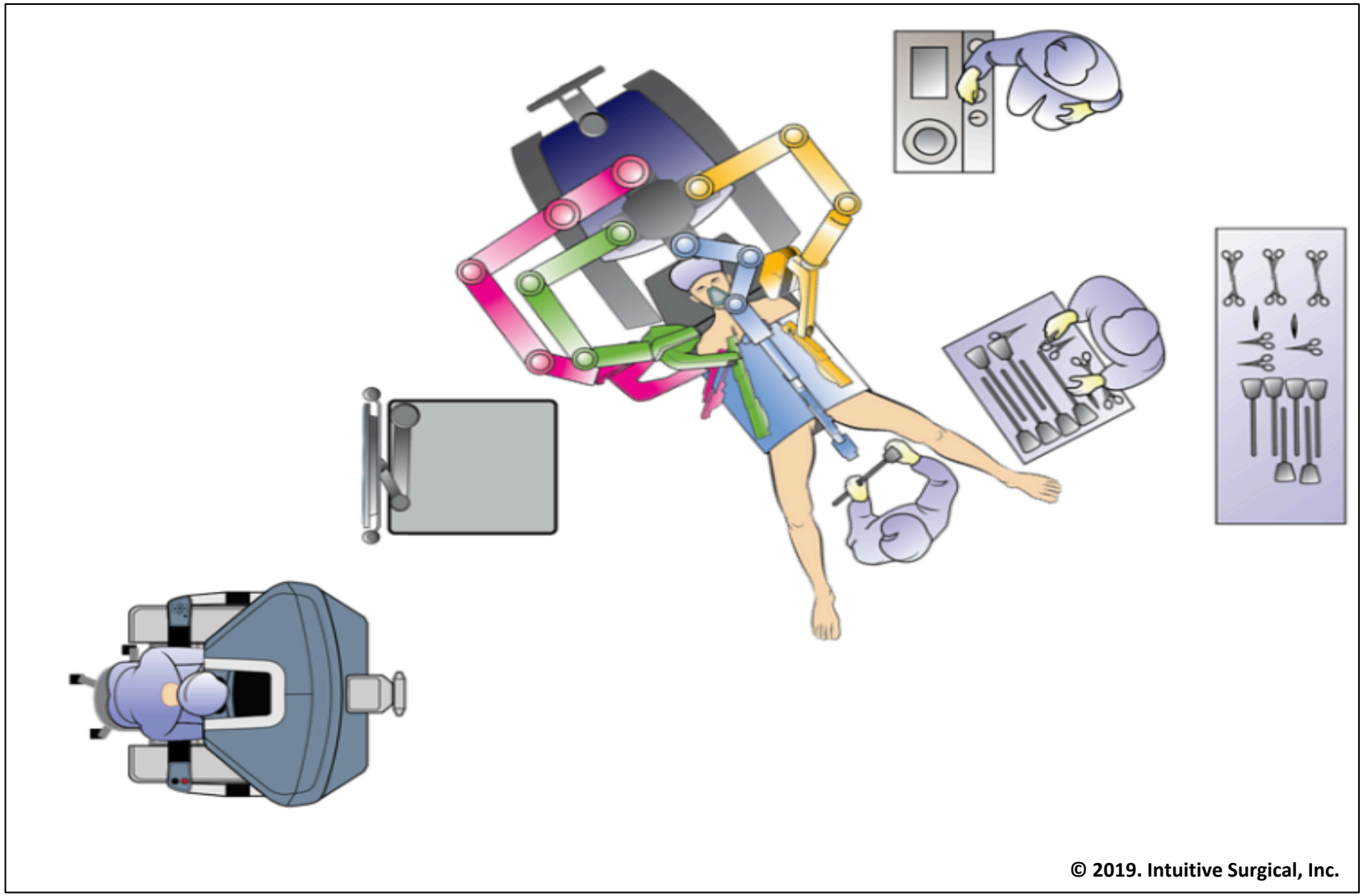

Figure

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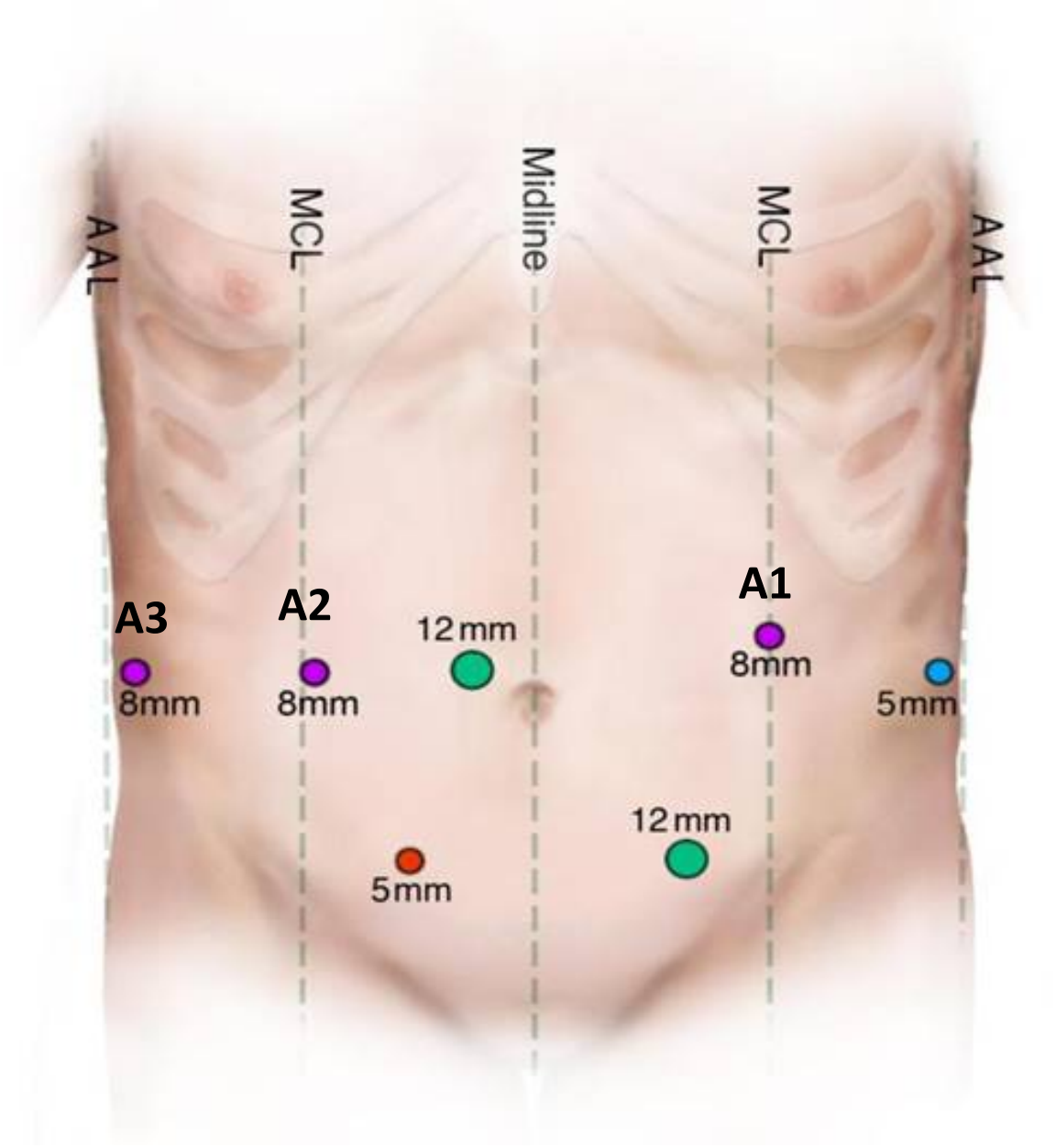

Clinicopathologic Treatment and Outcome Data, adopted from Zureikat, AH et al. Ann Surg. 2016.

Variable	All Patients	RPD	OPD	P-value	Represented Case
Age	65	67	65	0.07	44
Male sex, %	52.90%	55.45	52.26	0.41	Female
BMI, kg/m2	26.3	27.5	26.1	**<0.001**	24.41
Prior abdominal surgery, %	43.8	51.18	41.86	**<0.001**	None
Pancreatic cancer, %	50.8	33.18	55.32	**<0.001**	Yes
Pancreatic duct diameter (>8mm), %	6.3	15.74	3.55	**<0.001**	1 mm
Pancreatic texture (Soft), %	49.2	69.43	43.35	**<0.001**	Soft
Operative time, min	325	402	300	**<0.001**	225
Estimated blood loss	300	200	300	**<0.001**	50
Transfusion, %	16.4	16.11	16.52	0.89	None
Major complications, %	23.8	23.7	23.87	0.96	None
Severe wound infection, %	13	11.37	13.41	0.43	None
Pancreatic Fistula (Grade B/C), %	23.8	13.7	9.1	0.04	None
Length of stay, days	8	8	8	0.98	6

Name of Material/ Equipment	Company	Catalog Number
3-0 V-Loc sutures	Medtronic (Minneapolis, MN)	VLOCMo614
4-5 Fr Freeman Pancreatic Flexi-Stent	Hobbs Medical (Stafford Springs, CT)	6542, 6552
5-0 PDS (polydiosxanone)	Ethicon (Somerville, NJ)	D10063
Cadíere forceps	Intuitive (Sunnyvale, CA)	470049
Da Vinci Si	Intuitive (Sunnyvale, CA)	
Da Vinci Xi	Intuitive (Sunnyvale, CA)	
Endo Clip 10 mm Applier	Covidien (Dublin, Ireland)	176619
Endo GIA 45 mm Curved Tip Articulating Vascular Stapler with Tri-Stapler Technology	Covidien (Dublin, Ireland)	EGIA45CTAVM
Endo GIA 60 mm Articulating Stapler with Tri-Stapler Technology	Covidien (Dublin, Ireland)	EGIA60AMT
Endo GIA 60 mm Curved Tip Articulating Vascular Stapler with Tri-Stapler Technology	Covidien (Dublin, Ireland)	EGIA60CTAVM
EndoCatch Gold 10 mm Specimen Pouch	Medtronic (Minneapolis, MN)	173050G
EndoCatch II 15 mm Specimen Pouch	Medtronic (Minneapolis, MN)	173049
Fenestrated bipolar forceps	Intuitive (Sunnyvale, CA)	470205
GelPOINT Mini Advanced Access Platform	Applied Medical (Rancho Santa Margarita, CA)	CNGL3
Large needle driver	Intuitive (Sunnyvale, CA)	470006
Large SutureCut needle driver	Intuitive (Sunnyvale, CA)	470296
LigaSure Blunt Tip Laparoscopic Sealer/Divider	Medtronic (Minneapolis, MN)	LF1844
Mediflex liver retractor	Mediflex (Islandia NY)	
Monopolar curved scissors	Intuitive (Sunnyvale, CA)	470179
Permanent cautery hook	Intuitive (Sunnyvale, CA)	470183
ProGrasp forceps	Intuitive (Sunnyvale, CA)	470093

Comments/Description
Barbed Absorable Suture
Pancreatic Duct Stent
Synthetic Absorbable Suture
Surgical Robot Instrument
Surgical Robot
Surgical Robot
Laparoscopic Titanium Clip Applier
Laparoscopic Surgical Stapler
Laparoscopic Surgical Stapler
Laparoscopic Surgical Stapler
Specimen Extraction Bag
Specimen Extraction Bag
Surgical Robot Instrument
Laparoscopic Abdominal Access Platform
Surgical Robot Instrument
Surgical Robot Instrument
Laparoscopic Bioplar Device
Laparoscopic Liver Retractor
Surgical Robot Instrument
Surgical Robot Instrument
Surgical Robot Instrument

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Author(s):	Alex C. Kim, M.D./Ph.D., Rebecca C. Rist, B.A., Amer H. Zureikat, M.D.

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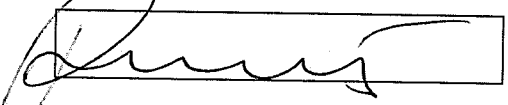
CORRESPONDING AUTHOR

Name:	Amer H. Zureikat, M.D.
Department:	Department of Surgery, Division of GI Surgical Oncology
Institution:	University of Pittsburgh Medical Center
Title:	Associate Professor of Surgery Chief, Division of GI Surgical Oncology Co-Director, UPMC Pancreatic Cancer Center
Signature:	
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1. Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues. The JoVE editor will not copy-edit your manuscript and any errors in the submitted revision may be present in the published version.

- **All the spelling and grammar issues were checked and resolved.**

2. We cannot have colon and the name of the university in the title of the manuscript. Please make the title concise reflecting the protocol in generic terms.

- **University name has been taken off the title and title was made concise.**

3. Please rephrase the Short Abstract/Summary to clearly describe the protocol and its applications in complete sentences between 10-50 words: "Here, we present a protocol to …"

- **Short Abstract/Summary was revised to reflect the recommendation.**

4. Please ensure that the Introduction includes all of the following:
a) A clear statement of the overall goal of this method

- **A clear statement goal is provided in the last sentence of the introduction**.

b) The rationale behind the development and/or use of this technique

- **The rationale behind the development and its use is added with supporting references.**

c) The advantages over alternative techniques with applicable references to previous studies

- **This has been inserted with supporting references. The advantage of the robotic-assisted PD is the ability to perform minimally invasive operation without the disadvantages of laparoscopy such as non-3D vision, non-wristed instruments, and poor ergonomics.**

d) A description of the context of the technique in the wider body of literature

- **The description has been provided with supporting references. The robotics PD allows for efficient operation comparable to open PD with safe oncologic dissection, hemostasis and meticulous reconstruction.**

e) Information to help readers to determine whether the method is appropriate for their application

- **This information has been added with references.**

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- **Majority of the company names were taken off the protocol section.**

6. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., “Do this,” “Ensure that,” etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as “could be,” “should be,” and “would be” throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a “Note.” However, notes should be concise and used sparingly.

- **The protocol was edited to reflect imperative tense.**

7. Please use complete sentences throughout as if describing how to perform your experiment with all specific details.

- **The protocol was edited to utilize complete sentences.**

8. The Protocol should contain only action items that direct the reader to do something.

- **The protocol was edited to reflect the comments.**

9. Please ensure that individual steps of the protocol should only contain 2-3 actions per step.

- **The protocol was edited to reflect the comments.**

10. Please ensure you answer the “how” question, i.e., how is the step performed?

- **The protocol was edited to reflect the comments.**

11. 2.3: please include the amount and concentration of the antibiotics used.

- **The concentration subcutaneous heparin was inserted. Antibiotics dosage differs with body weight and renal function, and we can not insert a uniform dose**

12. 4.2: How do you perform the laparoscopy?

- **Details of the laparoscopy are now concisely explained.**

13. 4.4, 5.1: Please use complete sentences throughout.

- **The protocol was edited to reflect the comments.**

14. Please ensure that the protocol is no more than 10 pages including all the headings and spacings.

- **The protocol portion of the manuscript is now 8 pages**

15. Please include a figure or a table in the Representative Results showing the effectiveness of your technique backed up with data. Maybe pre and post-operative comparison of data.

- **Table 1 comparing the represented case to the national data has been placed.**

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- **Explicit copyright permission was obtained and is accompanying the revisions. The figure legend was also edited to reflect the appropriate citation.**

17. As we are a methods journal, please revise the Discussion to explicitly cover the following in detail in 3-6 paragraphs with citations:
a) Critical steps within the protocol
- **This is described in paragraph 5. We highlighted the three critical steps which are dissection of LT, dissection of inferior pancreatic border and dissection of the uncinate process.**

b) Any modifications and troubleshooting of the technique
- **This is described in paragraphs 3-5. We particularly stressed the importance of the learning curve resulting in decrease in operative time, EBL, and pancreatic fistula. In addition, we explained the stepwise mastery-based curriculum along with references.**

c) Any limitations of the technique
- **This is described in paragraph 5. A particular challenge to RPD is encountered during hemorrhage. The difficulty in managing life-threatening hemorrhage is a limitation and often requires conversion to an open operation.**

d) The significance with respect to existing methods
- **This is described in paragraph 2. RPD results in decreased conversion compared to laparoscopy, and is also associated with improved morbidity and decreased length of stay in comparison to open PD.**

e) Any future applications of the technique
- **None**

Video:

1. Please include an ethics statement before the numbered protocol steps, indicating that the protocol follows the guidelines of your institution's human research ethics committee.

2. Please use imperative tense for the narration in the protocol section describing how to perform the procedure
- **The protocol was edited to reflect the comments.**

3. Please increase the homogeneity between the written protocol and the narration in the video. It would be best if the narration is a word for word from the written protocol text.
- **Done**

Production comments:

• 0:00-0:28, 13:46-14:34 - The UPMC logo should be removed from the video at these points. It can remain at the end of the video.

• 0:00-0:31 - There are slight black borders at the top and bottom of the frame during this time. The backgrounds should be extended to fill in these borders.
• The quality of the narration audio changes significantly over the course of the procedure section of the video. It seems to alternate between two different recording sessions, one of which has significant reverb on the voice. Nothing here is not able to be understood, but it would sound a lot better if it were redone all in one recording session.
• 4:00-4:03 - It sounds like part of a sentence was rerecorded here and spliced together with the other half of the sentence. The result is a bit confusing, as the sound quality and the inflection don't match. This should be rerecorded as a single sentence.
• 13:45 - A title card that reads "Outcomes" or "Results" should be inserted here.
• 14:26 - A title card that reads "Conclusion" should be inserted here.

- **These have been performed**

Reviewers' comments:
Reviewer #1:
Manuscript Summary:
I enjoyed reading this manuscript. It was nicely written and easily understood. It will help other programs to start the robotic whipple procedure.

Major Concerns:
Many programs are using DaVinci Xi system. Can the authors elaborate the differences between Si and Xi systems? What are the advantages of using Si to do whipple procedure?

- **The Si is an older system and is the basis for which the authors have performed the vast majority of RPDs. The main inherent advantage of Si is the use of a larger robotic camera with improved definition. However, the authors have used Si or Xi (more recently) for RPD interchangeably. This has been added to the text.**

Minor Concerns:
None

Reviewer #2:
Manuscript Summary:
Thank you for the opportunity to review this manuscript. Well written. Only minor concerns

- **We very much appreciate the review.**

Major Concerns:
none

Minor Concerns:
Please add the reference below. Kornaropoulos M, Moris D, Beal EW, Makris MC, Mitrousias A, Petrou A, Felekouras E, Michalinos A, Vailas M, Schizas D, Papalampros A.
Surg Endosc. 2017 Nov;31(11):4382-4392. doi: 10.1007/s00464-017-5523-z. Epub 2017 Apr 7. Review.
PMID: 28389798

- **The references was added within the discussion section.**

Reviewer #3:
Manuscript Summary:
The manuscript offers an optimal description regarding author's technique. I appreciate how each step is explained. The goal of allowing the reproduction of the technique is achieved. Some minor concerns regarding video are addressed.

Minor Concerns:
-Absence of presentation of the main robotic and laparoscopic instruments;
- **Due to the time limitation of the video, the description of the robotic and laparoscopic instruments are listed in the written protocol and tables of materials.**

-Increase in audio speed in some passages (as, for example, in the presentation of the case)
- **Edits were made as recommended**.

-Increase in video speed in some passages (as, for example, in the gastrojejunostomy)
- **Edits were made as recommended.**

-Too short presentation of hepaticojejunostomy
- **Edits were made as recommended.**

Reviewer #4:
Manuscript Summary:
This is an excellent description of the steps necessary to perform a robotic duodenopancreatectomy from one of the premier centers in the World.
- **Thank you and we appreciate your review.**

Major Concerns:
None

Minor Concerns:
None

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