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Robotic Total Pancreatectomy with or without Autologous Islet Cell Transplantation: Replication of an Open Technique through a Minimal Access Approach

Amer H. Zureikat, MD¹, Trang Nguyen, MD¹, Brian A. Boone, MD¹, Martin Wijkstrom, MD², Melissa E. Hogg¹, Abhinav Humar, MD², and Herbert Zeh III, MD¹

¹Division of GI Surgical Oncology, Department of Surgery University of Pittsburgh Medical Center Pittsburgh, PA

²Division of Transplantation, Department of Surgery University of Pittsburgh Medical Center Pittsburgh, PA

Abstract

Background—Total Pancreatectomy (TP) is a morbid but sometimes necessary operation. Robotic TP is not often reported but may harbor some advantages compared to the open approach. This manuscript details a single institutions outcomes and technique of robotic TP. An accompanying video demonstrates a robotic TP with auto islet cell transplantation (IAT) in which: 1) the arterial blood supply and venous drainage are kept intact until the last step of the total pancreatectomy to minimize warm ischemia time and 2) extirpation of the entire pancreas is performed without dividing the pancreatic neck to maximize islet recovery.

Methods—A retrospective review of a prospective database of perioperative outcomes of all consecutive robotic TPs at a single institution. This included a single robotic TP with IAT performed on a twenty-year-old patient with chronic pancreatitis.

Results—Between 2010 and January 2014, ten robotic TPs were performed (7 males, mean age 58 years), one of which included an IAT. Median body mass index was 28. Indications were intraductal papillary mucinous neoplasms (6), pancreatic adenocarcinoma (1), and chronic pancreatitis (3). The median operative time was 560 minutes with a median estimated blood loss of 650 ml. One case was converted to laparotomy. Ninety day mortality and Clavien III-IV complication rate was 0 and 20% respectively. The average length of stay was 10 ± 3 days, with only 1 readmission within 90 days. The single TP and IAT was completed successfully without conversion, and was achieved without division of the pancreatic neck thereby maintaining vascular inflow to an entire specimen up until extraction.

Conclusion—This represents the largest series of robotic TP, demonstrating its safety and feasibility. Additionally, TP and IAT using the technique described above can be recapitulated using the robotic approach.

Corresponding Author: Amer H. Zureikat, MD, FACS 5150 Centre Avenue, Suite 418 Pittsburgh, PA 15232 Ph: 412-623-7931 Fax: 412-692-2520 zureikatah@upmc.edu.

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Keywords

Robotic Assisted Surgery; Chronic Pancreatitis; Autologous islet transplantation; pancreatectomy

Introduction

Total pancreatectomy (TP) is an operation that is seldom performed and is associated with significant morbidity [1-3]. Indications for TP include extension of a pancreaticoduodenectomy or distal pancreatectomy in the face of persistent positive adenocarcinoma margins, IPMN in which the entire gland is considered a 'field defect', and chronic pancreatitis unresponsive to medical or surgical treatment [4]. Pancreatic islet cell auto transplantation (IAT) - a recognized treatment for chronic pancreatitis that aims to simultaneously alleviate pain and maintain endocrine function- is an indication for TP that is being increasingly performed at specialized centers. Despite significant improvements in the perioperative care of other of pancreatic resections, TP remains an independently poor predictor of postoperative outcomes compared to other pancreatic resections [1, 3].

Traditionally, the conduct of a TP (with or without IAT) typically involves two phases that evolve around division of the pancreatic neck; a distal pancreatectomy and a pancreaticoduodenectomy. Although many factors contribute to successful IAT, viable islet cell yield has been suggested to correlate positively with insulin independence after TP and IAT [5-7]. Islet cell yield can be maximized by early patient referral that precedes substantial gland fibrosis, development of diabetes, and prior pancreatic surgery. From a technical standpoint, keeping warm ischemic time to a minimum may also be important in optimizing islet cell yield. Recently, a novel technique of TP-IAT was described by Desai et al. in which the pancreatic neck is not divided, and the entire gland is extirpated as one specimen [8]. This strategy may improve islet cell yield and increase the success of IAT.

Minimally invasive pancreatic resections are being increasingly reported, however a fraction of these have dedicated outcomes pertaining to TP. We have recently adopted the robotic platform in the surgical treatment of pancreatic diseases as it allows complex pancreatic resections and reconstructions to be performed with principles identical to the open approach [9]. We report here the outcomes and technique of all robotic TPs at a single institution, including a single case of robotic TP with IAT performed without division of the pancreatic neck, analogous to the open technique described above [8]. An accompanying video details the technique of the robotic TP-IAT.

Methods

A retrospective review of perioperative outcomes of all consecutive robotic TPs at the University of Pittsburgh Medical Center was performed. This was conducted as part of an institutionally approved Quality Assurance/Quality Improvement project under institutional review board approval (IRB approval #14010003). Procedures reviewed included a single case of robotic TP-IAT performed for a twenty-year-old male with a 13-year history of chronic pancreatitis secondary to pancreas divisum and an L997F mutation in the CFTR

gene. Analysis was performed on an intent-to-treat basis. Outcomes were followed to 90 days. Morbidity was assessed using the Clavien-Dindo classification [10].

Operative technique for robotic TP with and without IAT (see accompanying video)

Patient positioning and port placement—Patients were placed supine and both arms were tucked on a split leg table. Port placement for the robotic TP is depicted in Figure I. A 12-mm camera port was placed approximately 2–3 cm above and to the right of the umbilicus to improve visualization of the lateral border of the portal vein. The robotic 8-mm ports were placed to the left (R1) and to the right (R2 and R3) of the umbilicus. Two assistant laparoscopic ports were placed approximately 4–5 cm caudal to the camera port along the left (10mm port) and right (5mm port) mid-clavicular lines respectively. A 5-mm port was placed in the left subcostal/anterior axillary line for a self-retaining liver retractor.

Step 1: Mobilization of the right colon and duodenum: The first phase of the TP involved laparoscopic mobilization of the right colon. The hepatic flexure attachments of the right colon were divided down to the terminal ileum, and an exaggerated medial visceral rotation was performed to expose the superior mesenteric vein (SMV) at the root of the small bowel mesentery. Next, an extended Kocher maneuver (Figure II) was performed to mobilize the duodenum from the ligament of Treitz beneath the mesenteric vessels. This maneuver allowed the jejunum to be pulled into the right upper quadrant under the mesenteric vessels and transected with a linear cutting stapler approximately 10 cm from the ligament of Treitz. The short jejunal mesenteric vessels were taken with the LigaSure (Covidien, Mansfield, MA) device. The jejunum was sutured to the stomach in antecolic fashion 50 cm downstream using a single suture to signal the location of the future gastrojejunostomy.

Step 2: Entrance into the lesser sac and division of the stomach/duodenum: The gastrocolic omentum was divided by taking down the short gastrics to the angle of His using the LigaSure device, and the posterior stomach was freed from the anterior surface of the pancreas. The distal stomach was then transected with a 4.8-mm linear cutting stapler.

Step 3: Docking the robot: Patients were positioned in slight reverse Trendelenburg position. The robot was docked directly over the head of the table. The robotic surgeon occupied the da Vinci console and the laparoscopic assistant stood between the patient's legs to exchange instruments, pass needles, and manage the suction-irrigator, clip appliers, LigaSure and stapler as needed.

Step 4: Dissection of the porta-hepatis and division of the bile duct: Using robotic hook cautery the superior border of the pancreas and the common hepatic artery (CHA) were exposed. We harvested the CHA lymph node routinely to aid exposure of the underlying vessel. The right gastric artery was divided between clips. The GDA was cleared of surrounding tissue and elevated with a vessel loop (Figure III). In the case of a TP, the GDA is transected with a vascular cartridge linear stapler, with enforcement of the stump using a 10 mm clip. For the TP-IAT, GDA transection is not performed until the just prior to specimen extraction to reduce warm ischemia time. The supra-pancreatic portal vein and the medial edge of the common bile duct (CBD) were then exposed, and all tissue was cleared

from the lateral border of the CBD, taking care to identify any aberrant right hepatic arterial anatomy. A vessel loop was passed behind the CBD, and the duct was transected with a linear stapler to prevent bile spillage.

Step 5: Dissection of the superior mesenteric vein (SMV), splenic vein (SV), and splenic artery (SA): The right gastroepiploic vein was followed to its origin to locate the SMV and the middle colic vein, and transected between clips, or the ligasure. The SMV was carefully freed from the inferior border and posterior neck of the pancreas allowing the tunnel over the portal vein to be completed under direct visualization. A moistened umbilical tape was passed around the neck (See Figure IV). In the case of a TP, the neck was divided with an EndoGIA stapler (Covidien, Mansfield, MA); For the TP-IAT, the neck was not divided in an attempt to preserve islet cell yield. Similarly, the splenic vein and artery are dissected and transected with vascular staplers, but are preserved (along with the GDA) in the case of a TP-IAT until the specimen extraction, thereby minimizing warm ischemia time (see step 8).

Step 6: En bloc medial to lateral mobilization of the pancreatic body, tail and spleen: The retroperitoneum on the inferior and superior border of the pancreas was incised laterally. The inferior mesenteric vein was encountered and controlled with a ligature or clips. The retropancreatic space was developed and included the SV, SA and pancreatic body and tail. The splenic flexure, spleno-renal and splenocolic ligaments were released. In this manner, the entire pancreatico-splenic complex was mobilized completely.

Step 7: Dissection of the pancreatic head and uncinate process: For a TP-IAT, anterior retraction on the umbilical tape around the pancreatic neck served to assist in mobilizing the pancreas from the lateral border of the SMV-PV. The dissection was performed in a caudal to cephalad direction. Inferiorly, the first jejunal branch was identified and preserved, with ligation of its small perforating uncinate branches with 3-0 silk or the LigaSure device. The superior pancreaticoduodenal vein (Vein of Belcher) was divided between 3-0 silk ligatures reinforced with 5-mm clips. Tiny branches were divided with the LigaSure device. Once the SMV-PV was reflected medially to the left, the SMA was identified posteriorly. Dissection proceeded along the plane of Leriche dividing the inferior and then the superior pancreaticoduodenal vessels between 2-0 silk ligatures or clips.

Step 8: Vascular division for TP-IAT: In the case of the TP-IAT, the entire (undivided) pancreas was 'lifted' from the retroperitoneum and was only attached by the GDA, SA and SV. Heparin was administered intravenously at 50 IU/kg. The three vessels were transected with a vascular load (Gold tip) stapler in the following sequence in order to minimize warm ischemia time and maximize the largest number of islet cells: SA, GDA, SV. A generous SV stump was retained to allow the introduction of a 14 gauge catheter for infusion of the islets (see step 10).

Step 9: Specimen extraction: A 15 mm bag was introduced through the left lower quadrant utility incision and the specimen was retrieved (Figure V).

Step 9: Reconstruction: The jejunum was brought up behind the root of the mesentery in 'neo duodenal' fashion and an end-to-side hepaticojejunostomy (Figure VI) was performed

in running fashion using 4-0 V-Loc (Covidien, Mansfield, MA) absorbable suture for medium to large ducts, and interrupted 5-0 PDS for small ducts. A Hoffmeister type, antecolic, handsewn end-to-side gastrojejunostomy was performed in two layers, using 2-0 silk for the outer layer, and 3-0 V-Loc (Covidien, Mansfield, MA) absorbable suture in a Connell fashion for the inner running layer.

Step 10: Islet cell infusion (TP-IAT): The splenic vein stump staple line was partially excised and a 14 gauge angiocath was easily manipulated into the portal vein. The catheter remained motionless in fixed position by the robotic arm. Sterile tubing connected the angiocath to the islet cell bag, and islet cells and digested exocrine tissue were infused into the portal vein by gravity (See Figure VII). The SV stump was restapled after the angiocath was removed.

Step 11: Drainage and closure: A 19 mm round Jackson-Pratt drain was left in the vicinity of the hepaticojejunostomy. The 12 mm port site and the left lower quadrant utility site were closed using interrupted 0-Polysorb.

Results

Overall Cohort

Between 2010 and January 2014 ten robotic TPs were performed; seven with splenectomy, two with splenic preservation, and one TP with IAT. Table I depicts patient demographics and characteristics. Operative indications were intraductal papillary mucinous neoplasms (n=6), pancreatic adenocarcinoma (n=1) and chronic pancreatitis (n=3 patients: 2 with PRSS1 mutations and 1 with a CFTR mutation). Table II describes operative and post-operative outcomes, while table III displays the operative time and estimated blood loss (EBL) by subtype of TP. One conversion to laparotomy was necessary due to significant inflammation that impeded safe dissection of the SMV. There was no 90-day mortality. Clavien-Dindo Grade III complications occurred in 2 patients (Grade 3A pleural effusion requiring thoracentesis and a Grade 3B post-operative fascial dehiscence at the specimen extraction site necessitating operative closure). The median length of stay was 10 days.

TP-IAT

The single patient undergoing TP-IAT had a total operative time (including islet cell preparation) of 607 minutes with an EBL of 200 ml. Excluding islet cell preparation, the operative time was 413 minutes. Following pancreas processing, the total islet yield was 255,000 islet equivalents (IEQ), corresponding to a total dose of 5,040 IEQ per kg body weight. Islets did not need to be purified. The portal pressure was 9 mmHg before infusion, and increased to 11 mmHg at the completion of pancreatic digest infusion 32 minutes later. He was discharged home on post-operative day 10 with no complications, on 10 units of Lantus plus a low-dose insulin sliding scale.

Discussion

This report represents the largest series of robotic TPs. A majority (90%) of cases were performed without conversion with outcomes that were equivalent to historic controls.

Additionally, we successfully performed a robotic TP-IAT in a twenty-year-old with hereditary chronic pancreatitis without dividing the pancreatic neck. This allowed extirpation of the entire gland as one specimen; a technique that may improve islet cell yields. Additionally, warm ischemia time was kept to a minimum thereby replicating principles of open TP and IAT.

Prior reports of TP are restricted to high volume centers, and indicate that the procedure is associated with considerable mortality and morbidity of up to 16% and 70% respectively [2, 11]. The three largest open series are summarized in table IV along with other minimally invasive series [2, 11-16]. Our report compares favorably to these historic controls, although selection bias is invariably present in favor of the robotic series.

In the context of performing a TP with IAT, the pancreas is usually divided early at the neck, and a distal pancreatectomy and splenectomy is performed first. The distal pancreatectomy specimen is processed for islets whilst dissection and extirpation of the pancreatic head and uncinate is performed. Performing a total pancreatectomy without dividing the pancreatic neck is postulated to reduce traumatic loss of islet cells. Moreover, maintaining vascular inflow to the specimen via the splenic artery and GDA until the very last step reduces warm ischemia time and may increase islet cell yield; the latter has been demonstrated to correlate favorably with post-operative insulin independence [5-7, 17]. In their novel report of 12 cases of open TP and IAT performed without division of the pancreatic neck, Desai et al. reported a mean operative time of 637 minutes, EBL of 641 ml, and a median auto-islet count of 325,166 (IEQ of 241,345, and IEQ/kg of 2,538) [8]. Our operative parameters are well within this and other reports. More recently, Galvani et al reported their experience with 6 robotic TP with IAT, with similar operative parameters [14, 18].

We have previously shown that robotic assisted major pancreatic resections and reconstructions are safe [9]. Performing a TP robotically may offer some advantages compared. First, the periumbilical angle at which the camera is placed allows the console surgeon better visualization of the retropancreatic/portal vein tunnel. Because the surgeon is looking 'into' the tunnel from caudal to cephalad, the entire head and uncinate can be meticulously dissected. This operative view also facilitates performing the TP without division of the pancreatic neck as was performed for the single case of IAT. Second, robotic dexterity and magnification can allow splenic preservation if desired by the surgeon. Third, reductions in EBL (an advantage that has been observed with other abdominal minimally invasive operations) may correlate with reduced postoperative morbidity after TP. Lastly and perhaps most importantly, many of the patients who undergo early TP and IAT are young adults with hereditary pancreatitis similar to the patient in this series. They not only have to deal with the physical and psychological trauma of CP, but also have to endure the pain and appearance of a major laparotomy scar after TP-IAT. The application of minimally invasive approaches to this patient population may inflict less pain and psychological trauma; potentially enhancing their recovery.

In conclusion, robotic TP in carefully selected patients can be performed safely for various indications with a variety of techniques. It is possible that larger operations such as TPs,

with their inherently substantial morbidity and reduction in quality of life, may prove to benefit the most from the robotic platform

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Bhayani NH, Miller JL, Ortenzi G, Kaifi JT, Kimchi ET, Staveley-O'Carroll KF, Gusani NJ. Perioperative outcomes of pancreaticoduodenectomy compared to total pancreatectomy for neoplasia. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract*. 2014; 18:549–554. [PubMed: 24165872]
2. Reddy S, Wolfgang CL, Cameron JL, Eckhauser F, Choti MA, Schulick RD, Edil BH, Pawlik TM. Total pancreatectomy for pancreatic adenocarcinoma: evaluation of morbidity and long-term survival. *Annals of surgery*. 2009; 250:282–287. [PubMed: 19638918]
3. Kneuert PJ, Pitt HA, Bilimoria KY, Smiley JP, Cohen ME, Ko CY, Pawlik TM. Risk of morbidity and mortality following hepato-pancreato-biliary surgery. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract*. 2012; 16:1727–1735. [PubMed: 22760965]
4. Heidt DG, Burant C, Simeone DM. Total pancreatectomy: indications, operative technique, and postoperative sequelae. *Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract*. 2007; 11:209–216. [PubMed: 17390175]
5. Ahmad SA, Lowy AM, Wray CJ, D'Alessio D, Choe KA, James LE, Gelrud A, Matthews JB, Rilo HL. Factors associated with insulin and narcotic independence after islet autotransplantation in patients with severe chronic pancreatitis. *Journal of the American College of Surgeons*. 2005; 201:680–687. [PubMed: 16256909]
6. Gruessner RW, Sutherland DE, Dunn DL, Najarian JS, Jie T, Hering BJ, Gruessner AC. Transplant options for patients undergoing total pancreatectomy for chronic pancreatitis. *Journal of the American College of Surgeons*. 2004; 198:559–567. discussion 568–559. [PubMed: 15051008]
7. Panaro F, Testa G, Bogetti D, Sankary H, Helton WS, Benedetti E. Auto-islet transplantation after pancreatectomy. Expert opinion on biological therapy. 2003; 3:207–214. [PubMed: 12662136]
8. Desai CS, Stephenson DA, Khan KM, Jie T, Gruessner AC, Rilo HL, Gruessner RW. Novel technique of total pancreatectomy before autologous islet transplants in chronic pancreatitis patients. *Journal of the American College of Surgeons*. 2011; 213:e29–34. [PubMed: 21996486]
9. Zureikat AH, Nguyen KT, Bartlett DL, Zeh HJ, Moser AJ. Robotic-assisted major pancreatic resection and reconstruction. *Archives of surgery*. 2011; 146:256–261. [PubMed: 21079111]
10. DeOliveira ML, Winter JM, Schafer M, Cunningham SC, Cameron JL, Yeo CJ, Clavien PA. Assessment of complications after pancreatic surgery: A novel grading system applied to 633 patients undergoing pancreaticoduodenectomy. *Annals of surgery*. 2006; 244:931–937. discussion 937–939. [PubMed: 17122618]
11. Janot MS, Belyaev O, Kersting S, Chromik AM, Seelig MH, Sulberg D, Mittelkötter U, Uhl WH. Indications and early outcomes for total pancreatectomy at a high-volume pancreas center. *HPB surgery : a world journal of hepatic, pancreatic and biliary surgery* 2010. 2010
12. Dokmak S, Aussilhou B, Sauvanet A, Ruszniewski P, Levy P, Belghiti J. Hand-assisted laparoscopic total pancreatectomy: a report of two cases. *Journal of laparoendoscopic & advanced surgical techniques Part A*. 2013; 23:539–544. [PubMed: 23551033]

13. Choi SH, Hwang HK, Kang CM, Yoon CI, Lee WJ. Pylorus- and spleen-preserving total pancreatoduodenectomy with resection of both whole splenic vessels: feasibility and laparoscopic application to intraductal papillary mucin-producing tumors of the pancreas. *Surgical endoscopy*. 2012; 26:2072–2077. [PubMed: 22237756]
14. Galvani CA, Rodriguez Rilo H, Samame J, Porubsky M, Rana A, Gruessner RW. Fully robotic-assisted technique for total pancreatectomy with an autologous islet transplant in chronic pancreatitis patients: results of a first series. *Journal of the American College of Surgeons*. 2014; 218:e73–78. [PubMed: 24559970]
15. Bhayani NH, Enomoto LM, Miller JL, Ortenzi G, Kaifi JT, Kimchi ET, Staveley-O'Carroll KF, Gusani NJ. Morbidity of total pancreatectomy with islet cell auto-transplantation compared to total pancreatectomy alone. *HPB : the official journal of the International Hepato Pancreato Biliary Association*. 2013
16. Muller MW, Friess H, Kleeff J, Dahmen R, Wagner M, Hinz U, Breisch-Girbig D, Ceyhan GO, Buchler MW. Is there still a role for total pancreatectomy? *Annals of surgery*. 2007; 246:966–974. discussion 974-965. [PubMed: 18043098]
17. Sutherland DE, Gruessner AC, Carlson AM, Blondet JJ, Balamurugan AN, Reigstad KF, Beilman GJ, Bellin MD, Hering BJ. Islet autotransplant outcomes after total pancreatectomy: a contrast to islet allograft outcomes. *Transplantation*. 2008; 86:1799–1802. [PubMed: 19104425]
18. Galvani CA, Rilo HR, Samame J, Gruessner RW. First fully robotic-assisted total pancreatectomy combined with islet autotransplant for the treatment of chronic pancreatitis: a case report. *Pancreas*. 2013; 42:1188–1189. [PubMed: 24048458]

Figure I.

Port Placement for Robotic TP

Periumbilical 12 mm port (green): Robotic camera

Upper 8 mm ports (purple): Robotic arms. R1= Left MCL, R2= Right MCL, R3= Right AAL.

Left AAL 5 mm port (blue): Self retaining retractor

Left Lower Quadrant 12 mm port (green): Laparoscopic assistant port and Specimen extraction site (3-4cm Single incision Gelport)

Right Lower Quadrant 5 mm port (red): laparoscopic assistant port.

Figure II.

Laparoscopic Kocher maneuver exposing the IVC posteriorly. The gallbladder is noted at the top of the screen

Figure III.

Isolation of the GDA. This is divided with a linear vascular stapler early in the TP, but preserved as the final maneuver in the TP-IAT in order to reduce warm ischemia time

Figure IV.
Pancreatic neck tunnel: An umbilical tape is passed around the pancreatic neck. The umbilical tape facilitates retraction of the neck during dissection of the head and uncinate in a TP-IAT.

Figure V.
Resection bed following total pancreatectomy specimen removal: PV – Portal Vein, SMV – Superior Mesenteric Vein.

Figure VI.
Robotic hepaticojejunostomy using 4-0 running absorbable V-LOC suture over a 7 french stent.

Figure VII.
Islet Cell Infusion through a 14 G angiocath into the splenic vein stump.

Table I

Patient Demographics and Indications (n=10)

Patient Demographics	n
Male	7
Age years, mean $\pm$ SD (range), years	58 $\pm$ 16 (20 – 76)
Body Mass Index, median (IQR)	28.2 (24.5 - 29.75)
Age Adjusted Chalon Comorbidity Index – mean (range)	2.4 (0 – 9)
0	4
1-3	4
4-6	1
7	1
Prior Abdominal Operations	4 (40%)
Indication for Surgery	
Intraductal papillary mucinous neoplasms	6
Pancreatic adenocarcinoma	1
Chronic pancreatitis	3
PRSS1 mutation	2
CFTR mutation	1

IQR: interquartile range

Table II

Operative Parameters and Post-Operative Outcomes (n=10)

Operative Parameters	n (%)
Type of Operation	
Total Pancreatectomy and Splenectomy	7
Spleen Preserving Total Pancreatectomy	2
Total Pancreatectomy and Auto islet Transplantation	1
Operative Time - median (IQR), minutes	560 (461 - 592)
Estimated Blood Loss – median (IQR), ml	650 (400 – 1000)
0 – 500	4
501 – 1000	4
> 1000	2
Blood transfusions	2 (20%)
Conversion to Open	1(10%)
Post-Operative Outcomes	
90 day mortality	0
Maximum Clavien-Dindo Complications	
Grade I – II	8 (80%)
Grade III	2 (20%)
Pleural effusion requiring thoracentesis	1
Reoperation for fascial dehiscence	1
Reoperation	1(10%)
Length of Stay - mean $\pm$ SD (range)	10 $\pm$ 3 (7 – 18)
Readmissions within 30 days	1

IQR: interquartile range

SD: standard deviation

Table III

Operative Time and Estimated Blood Loss (EBL) by type of Robotic Total Pancreatectomy

	n	Operative Time Median (IQR), minutes	EBL median (IQR), ml
Robotic Assisted Total Pancreatectomy	10	560 (461 - 592)	650 (400 – 1000)
Completely Minimally Invasive	9	569 (436 - 598)	622 (400 – 1000)
With Splenectomy	6	560 (461 – 591)	500 (400 - 675)
Without Splenectomy	2	504 (470 - 538)	1050 (1025 – 1075)
With Auto islet Transfusion	1	607	200
Converted to Open	1	534	2500

Table IV

Selected Outcomes of Open, Laparoscopic and Robotic Total Pancreatectomies with or without IAT.

	# of Patients	Operation	Series Type	Pathology	Operative Time, median (Range), minutes	EBL, median (ml)	Intraoperative blood transfusion (%)	Major morbidity ⁺	Mortality	LOS (days), median (Range)
Bhayani et al. [1]	198	Open TP	NSQIP	Neoplasia	361	NR	10%	30%	3% (30 day)	10
Bhayani et al. [15]	126	Open TP	NSQIP	Chronic pancreatitis	310 (75-1140)	NR	7%	29%	3% (30 day)	9 (3-120)
Bhayani et al. [15]	191	Open TP + AIT	NSQIP	Chronic pancreatitis	530 (370-1007)	NR	20%	41%	1% (30 day)	13 (4-195)
Reddy et al. [2]	100	Open TP	Single center	PDA	433	1100	NR	69% (all morbidities, 59% were minor)	8% (30 day)	10 (6-64)
Muller et al. [16]	100	Open TP	Single center	Benign & Malignant	385 (IQR 327-435)	1000	NR	36%	6%	11 (IQ 8-14)
Janot et al. [11]	63	Open TP	Single center	Benign & Malignant	420	800	46%	50.80%	15.90% (30 day)	21 (7-108)
Dokmak et al. [12]	2	Laparoscopic TP	Single center	IPMN & Neuroendocrine	315 (270-360)	250	0%	NR	0%	15 (12-18)
Choi et al. [13]	3	Laparoscopic TP	Single center	IPMN	410 (410-450)	490	66.70%	NR	0%	21 (17-22)
Galvani et al. [14]	6	Robotic TP + AIT	Single center	Chronic Pancreatitis	712 [*] (612-835)	630 [*]	NR	0%	0%	12.6 [*] (11-14)
UPMC/Current series	10	Robotic TP ±AIT	Single center	Benign & Malignant	560 (341 – 616)	650	20%	20%	0% (90 day)	10 (7-13)

UPMC: University of Pittsburgh Medical Center
NSQIP: American College of Surgeons National Surgical Quality Improvement Program

TP: total pancreatectomy (open unless otherwise indicated)

AIT: auto-islet transfusion

IQR: interquartile range

LOS: length of stay

^{*} reported as mean

⁺ Major morbidity as defined by each series.