Robotic Assisted Pancreaticoduodenectomy

Brij B. Agarwal and Neeraj Dhamija

Introduction

Pancreatic cancer remains one of the deadliest malignancies even after the advancement in the diagnostic, surgical and adjuvant therapy. The first attempt for minimally invasive resection of the pancreatic head malignancy was made by Gagner and Pomp [1] in the year 1994. They concluded that there is no added benefit in performing laparoscopic pancreaticoduodenectomy [2]. Since then, there has been a very gradual increase in number of pancreatico-duodenectomies performed by minimally invasive route mostly due to improved optics and instruments along with reconstruction techniques. It was after the introduction and utilisation of Robotic platform to perform complex abdominal dissection and anastomosis; we have seen a consistent rise in the Robotic assisted pancreaticoduodenectomy (RAPD) or complete Robotic pancreaticoduodenectomy procedures (RPD).

There is a consistent increase in number of publications of both Robotic Assisted and Total Robotic pancreaticoduodenectomy procedure over the last decade [3–5]. There are many case series evaluating the advantages of the minimally invasive pancreaticoduodenectomy over the traditional open approach [3–8]. A recent randomized controlled trial- PORTAL trial is also under way comparing Robotic pancreaticoduodenectomy and open procedure [9].

When the Robotic platform is used for all the sub-steps of pancreaticoduodenectomy procedure starting from dissection to resection and reconstruction, the procedure is called as Total Robotic Pancreaticoduodenectomy procedure. Whereas when the robot is used only to perform specific sub-steps like creation of pancreatico-enteric anastomosis and bilio-enteric anastomosis after a

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D. Sharma, P. Hazrah (eds.), *Recent Concepts in Minimal Access Surgery*,
https://doi.org/10.1007/978-981-16-5473-2_5

laparoscopic resection then the procedure is called as Robotic Assisted Pancreaticoduodenectomy, and also called as robotic Hybrid pancreaticoduodenectomy. Irrespective of the operative platform the operative steps remain the same with an aim of providing the patient with similar/non inferior oncological outcome compared to open procedure [10].

Robotic surgery bridges the gap between open and minimally invasive route by imparting seven degrees of freedom and utilization of the endo-wrist instruments of the Da Vinci™ robotic system. This is advantageous while performing complex anastomosis. A successful resection and reconstruction by minimally invasive route will add up the advantages of early recovery and discharge from the hospital by limiting the parietal wound morbidity. The rate of other complications like postoperative pancreatic fistula, post pancreatectomy hemorrhage and delayed gastric emptying remains same or low as compared to the standard open technique.

In this chapter we describe the technique of performing a Robotic Assisted Pancreaticoduodenectomy (RAPD) procedure.

Patient Selection

In robotic pancreaticoduodenectomy procedure, the ideal favorable patient profile is:

a. Small [<2 cm] periampullary lesions and head of pancreas lesion.
b. Age of the patient <65 years
c. Acceptable co-morbidity profile

With experience more complex cases are being done by utilization of the robotic platform stretching out the limits of above said patient profile to locally advanced pancreatic neoplasms which require difficult dissection and vascular resection.

In high volume centers with experienced surgeons, post neoadjuvant chemotherapy cases and those requiring vascular resections are no longer a contraindication for RPD. Reports are available of known aberrant RHA being managed during RPD, while definite better outcome is seen in obese patients on using the robotic platform [8, 11–13].

Technique of Robotic Assisted Pancreaticoduodenectomy [RAPD]

Patient is anesthetized and intubated by the anesthesiologist. Position of the patient is reverse Trendelenburg with leg split or the French position. The Robotic platform used is Da Vinci Si, docked from the head end. For the laparoscopic part of the procedure, operating surgeon stands between the legs of the patient and camera and assistant surgeon on either side of the patient. Table 1 outlines the steps of robotic assisted pancreaticoduodenectomy.

Table 1 Steps of Robotic Assisted Pancreatico-Duodenectomy

Steps of Robotic Assisted Pancreatico-Duodenectomy	
1.	Diagnostic Laparoscopy
2.	Opening of Gastrocolic Omentum
3.	Gastrocolic Vessels Dissection
4.	Cattle-Braasch Maneuver [Mobilisation of the Right Colonic Flexure and Extended Kocherization]
5.	Hilum Exploration
6.	Gastroduodenal Artery Dissection
7.	Retro-Pancreatic Tunnel
8.	Transection of the Stomach
9.	Pancreatic Neck Transection
10.	Transection of First Jejunal Loop and Ligament of Trietz
11.	Cholecystectomy
12.	Common Bile Duct Transection
13.	Uncinate Process Dissection
14.	Specimen Extraction
15.	Docking of Robot for Reconstruction
16.	Pancreatico-Jejunostomy
17.	Hepatico-Jejunostomy
18.	Undocking of Robot
19.	Gastro-Jejunostomy
20.	Drain Placement and Closure

Diagnostic Laparoscopy

After painting and draping, pneumoperitoneum is created with the palmer's point approach. Staging laparoscopy is done with 5 mm, 30-degree telescope. The parietal and visceral surface of the peritoneum is inspected carefully for any nodules with suspected metastasis. The peritoneal cavity is inspected for the presence of any free fluid. In the presence of any nodule or free fluid the samples are taken for assessment by frozen technique to confirm for metastatic disease which will direct the further course of surgical management. The standard port position for Robotic Assisted Pancreatico duodenectomy is shown in the Fig. 1.

Opening Gastrocolic Omentum

The next step is to enter the lesser sac by opening of the gastrocolic omentum. This step is aided by using the ultrasonic shear dissection and can be easily done by dissecting the gastrocolic omentum at the midpoint between the greater curvature and the colonic margin. The window thus created in the gastrocolic omentum is widened both cranially and to the right so that the entire posterior surface of the stomach is clearly seen. Pancreas along with the covering off the posterior peritoneal lining can be seen at the posterior aspect of the lesser sac. The adhesions between the posterior surface of the stomach and the pancreas are divided.

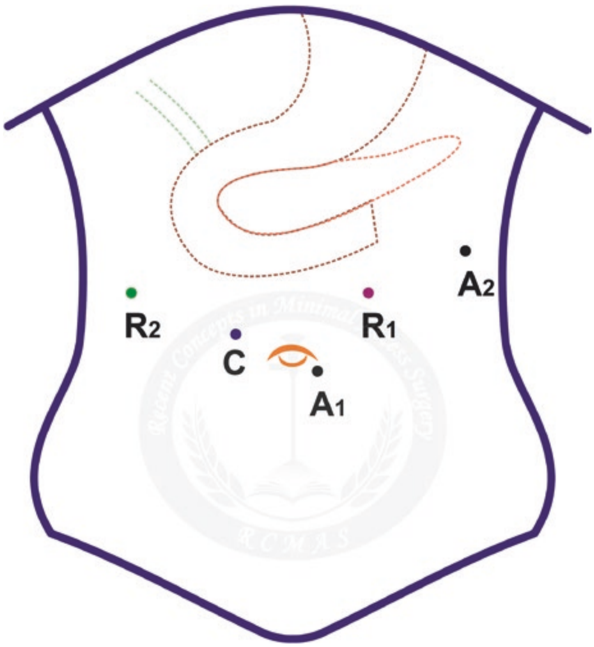

Fig. 1 Port Placement in Robotic Pancreatico duodenectomy Procedure System Used Da Vinci Si; C = Camera Arm of Robot (2 cm above and lateral to the umbilicus on the right side); R1 = Right Hand of Operating Surgeon- Working Arm 1 (Left Mid clavicular line 8 cm from the Camera Port); R2 = Left Hand of Operating Surgeon- Working Arm 2 (Just Lateral to the Right mid clavicular line, 8cm from the Camera Port); A1 = Assistant Port 10mm (1cm below and lateral to the umbilicus on the left side); A2 = Assistant Port 5mm (Anterior axillary line on the left side 5 cm from the R1)

Ligation of the Gastrocolic Vessels

While dissecting the gastrocolic omentum medially towards the duodenum the gastrocolic vessels are encountered which should be carefully dissected and clipped separately. This usually ensures the complete mobilisation of the whole of the greater curvature of the stomach all along till the duodenum.

Cattle-Braasch Maneuver [Mobilisation of the Right Colonic Flexure and Extended Kocherization]

At this point the cattle-braasch maneuver and extended kocherization is done [Fig. 2]. This important step aids in the future dissection of the uncinate.

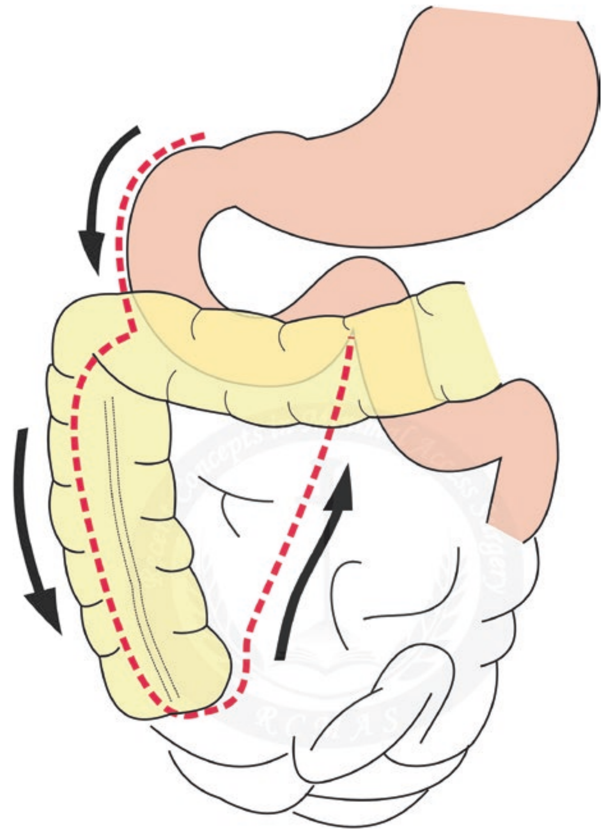

Fig. 2 Cattell-BraaschManuever: (Extended Kocher + Incision of small bowel mesentery to posterior peritoneum to reflect the ascending colon and duodenum to the left side of abdomen)

Hilum Exploration

Dissection of the hepatoduodenal fatty tissue is performed next starting at the lesser curvature of the stomach. The common hepatic artery is identified, and dissection is done along the adventitial layer of the vessel which is usually avascular. Proper understanding of the vascular anatomy of individual case by a detailed study of the CT angiography will help and aid in the dissection. Careful dissection will eventually dissect all the fatty tissue along with the lymph nodes which should be sent separately in an endobag or along with the main specimen for proper histopathological examination (HPE) and oncological evaluation.

Gastroduodenal Artery [GDA]Dissection

Dissection of the lymph nodes will also make the gastroduodenal artery [GDA] visible making it easy for dissection. GDA should always be double ligated with two clips on both proximal and distal side to safely secure this vessel [Fig. 3].

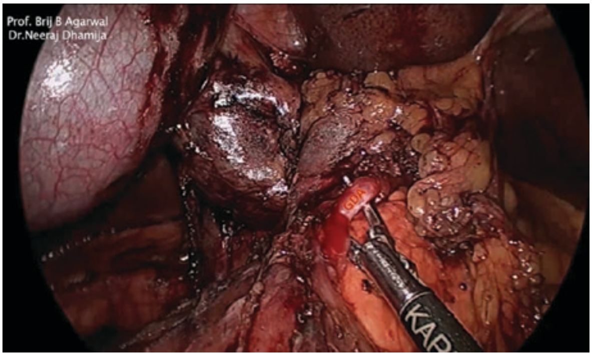

Fig. 3 Dissection and Ligation of Gastro Duodenal Artery

Just deep to the GDA is the portal vein which should be visible by now and on the right side is the CBD. We should carefully dissect the gastroduodenal vein which is usually present on the right side of GDA. When it is of a significant size, its injury can be a source of troublesome bleeding.

Retro Pancreatic Tunnel

At the lower border of the pancreas the mesopancreatic tissue is dissected to reveal the superior mesenteric vein (SMV). The site of SMV can be can be traced by following the previously ligated gastroepiploic vein which leads us to the SMV. Careful blunt dissection is done with the help of atraumatic grasper or the suction tip. Usually, this plane is not having any major vessels but occasionally one or more direct venous tributaries may be seen arising from the posterior surface of the pancreas and draining into the SMV. These can be easily secured with either harmonic scalpel or haemolock clips. The space behind the pancreatic neck is further dissected to reach and meet the already created superior space at the level of GDA vessel and just medial to it.

Vessel First Approach During a suspected locally advanced lesion and possible involvement of the vital vascular structures at the posterior aspect of the pancreas a vessel first approach is utilized for dissection. In this approach the feasibility of Step number 7 is assessed before Step Number 3, i.e. after the dissection of the epiploic vessels. The feasibility of the creation of the retropancreatic tunnel over the great veins- SMV and Splenic vein confluence to form Portal veinis ascertained. This modification of the technique is important as any abnormal adhesions between the posterior surface of the pancreas and the great veins will unable us to progress with the pancreatic neck transection and can result in unwanted bleeding which can be a catastrophe. This may demand conversion of the procedure to open or abandon the procedure for non-operability.

Transection of Stomach

Stomach is transected with the help of Endo stapler 60 mm green loads. Classical pancreatico duodenectomy describes transection of the stomach at the junction of middle and distal third. Usually, one to two cartridges are used for transection of stomach. Both side of the transected stomach is then opened like a book aiding in complete visualization of the pancreatic neck.

Pancreatic Neck Transection

A successful creation of the space will enable us for the next important step of pancreatic neck transection. The transection of the pancreas at the level of the neck-the region of the pancreatic neck is identified by posteriorly running superior mesenteric vein and splenic vein confluence to form portal vein. The line of transection is usually parallel to the portal vein. Ultrasonic scissors is preferably used for transection [Fig. 4]. The trick is to take small bites at minimum level of setting. Careful dissection will help us to identify the pancreatic duct which is also transected by cold scissors and the dissection is further continued from caudal to cranial fashion to complete the transection of the pancreas.

Transection of the Jejunum

After pancreatic transection, the omentum and the transverse colon is flipped-up to reveal the duodeno-jejunal junction [DJ] and the ligament of Trietz. Approximately 15 cm from the DJ, jejunum is transected with the help of a 60 mm white/blue stapler. The mesentery of the transected jejunum is resected close to the jejunal wall to reach the ligament of Trietz. Careful dissection of the ligament of Trietz makes the DJ free and this step enables us to deliver the transected jejunum to the right side of the abdomen through the retroperitoneal tunnel.

Fig. 4 Transection of the Neck of the Pancreas

Cholecystectomy

The CBD and the Calot's triangle are dissected, and the cystic artery is secured. The cystic duct is ligated in continuity but the gall bladder is not detached immediately from liver as it aids in the dissection of the important structures at the porta. The CBD is looped with silastic loop for identification and future transection.

Transection of the Bile Duct

After transection of the pancreas, the specimen is attached with the help of the uncinate process and the bile duct. The transection of the bile duct is usually done at the level of the cystic duct and bile duct confluence. The transected margin of the bile duct can be sent for frozen section if the indication of the resection is a distal cholangiocarcinoma. The transection is usually aided by the harmonic scalpel with care taken to remain away from the portal vein.

Transection of the Uncinate Process of the Pancreas

At this step the only structure which is holding the specimen is the uncinate process of the pancreas. The dissection of the uncinate process begins in a caudal-to-cranial fashion. Traction over the specimen side and counter traction by assistant surgeon over the portal vein will expose the mesopancreatic tissue in close proximity to the superior mesentric artery [SMA]. Careful dissection of the venous tributaries to the portal vein travelling through the uncinate and ligation of the small arteries from SMA to the uncinate is done with the help of Harmonic Scalpel and Haemolock clips/Ligaclips wherever necessary [Fig. 5].

Out of all the vessels in the region of the uncinate the "First jejunal vein" is the most notorious. It runs as a course of a 'U' shaped loop of vein traversing through the uncinate and therefore you have to either dissect it completely or secure it twice to have proper control of this vessel. This is a common source of bleeding from the

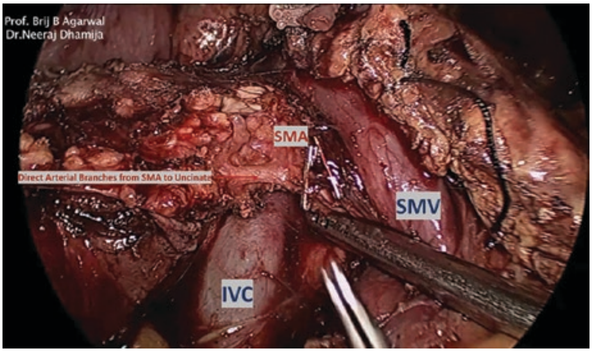

Fig. 5 Dissection of the Uncinate process of Pancreas

uncinate process while dissection. A step-by step approach is followed, and the vessels secured to reach and meet the cranial edge of the uncinate where it joins the already formed window of the dissected bile duct. This will complete the resection of the specimen of Pancreatico-Duodenectomy.

Specimen Extraction

The resected specimen is placed in an Endobag and retrieved from the port-site. The specimen can also be retrieved from Natural orifice -Vagina in consenting post-menopausal women undergoing minimally invasive pancreaticoduodenectomy with acceptable results.

Docking of the Robot for Reconstruction

The Robot is docked from the head end. In the robotic arm-1 a needle holder is equipped and in the robotic arm-2 atraumatic bowel grasper is equipped. The operating surgeon sits at the robotic console and the reconstruction is started.

Reconstruction After Robotic or Robot Assisted Pancreaticoduodenectomy
Reconstruction after the resection of the pancreaticoduodenectomy involves three technically challenging anastomosis. It consists of-

– Pancreatico-Jejunostomy [PJ]
– Hepatico-Jejunostomy [HJ]
– Gastro-Jejunostomy [GJ]

To begin the reconstructive phase, the transected jejunum approximately 15 cm from the DJ is brought to the right side through the retro-colic route by forming a window in the mesentery of the transverse colon. A single loop reconstruction is preferred by performing a series of reconstruction in order of a PJ, HJ & GJ.

Pancreatico-Jejunostomy [PJ]

Before we start doing the PJ, we make sure that there is adequate mobilization of approximately 3–5 cm of the pancreas in the posterior aspect so that the posterior surface of the pancreas is exposed. The reconstruction is done in an end-to-side fashion where the cut end of the pancreas is anastomosed to the side of the jejunum. Preferred technique is selective duct-to-mucosa suturing with dunking of the rest of the pancreas. It consists of a four layered anastomosis. The technique used by the authors is described here below:

I. The first layer consists of the interrupted 4-0 PDS (polydioxanone) sutures from the posterior surface of the pancreas and the sero-muscular layer of the jejunum. It is started at a distance of approximately 1 cm from the cut edge of the pancreas at the posterior surface. It usually takes about 6–8 sutures to complete this layer [Fig. 6].
II. The second layer is a selective duct-to-mucosa layer. As the duct of the pancreas is eccentrically located and is closer to the posterior aspect of the pancreas, selective sutures are taken between the posterior ductal margin and the posterior lip mucosa of the jejunal enterotomy. About 4 interrupted sutures with 4-0 PDS are required in this fashion. Rest of the second layer consists of the interrupted sutures with 4-0 PDS between the full thickness of the jejunum and the pancreatic parenchyma at the level of the duct where at least 2–3 sutures are taken both cranially and caudally to the duct of the pancreas. At this step a stent [silastic feeding tube of 5 cm and 6-8Fr] can be introduced into the duct of the pancreas and the intestinal lumen to create a stented anastomosis [Fig. 7].
III. The third layer of the PJ consists of a 6-8 interrupted 4-0 PDS sutures from the anterior surface of the cut edge of the pancreas and the anterior lip of enterotomy of the jejunum. Care must be taken for not tightening the sutures too much which can cause tear of the pancreatic parenchyma [Fig. 8].

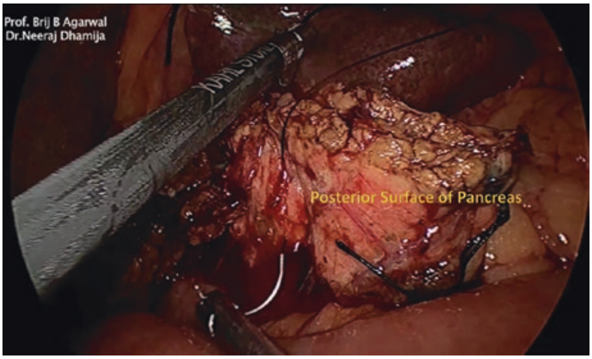

Fig. 6 Ist Layer of Pancreatico-Jejunostomy

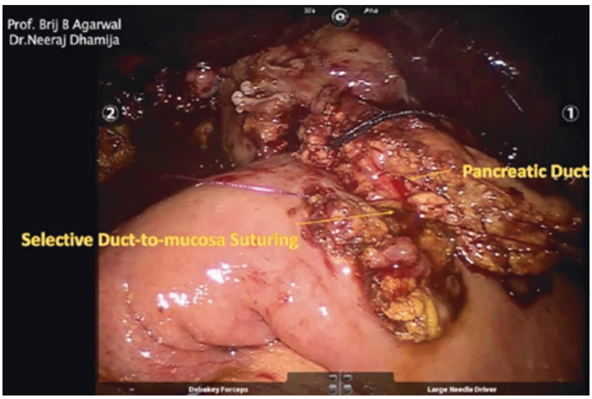

Fig. 7 IInd Layer of Pancreatico-Jejunostomy

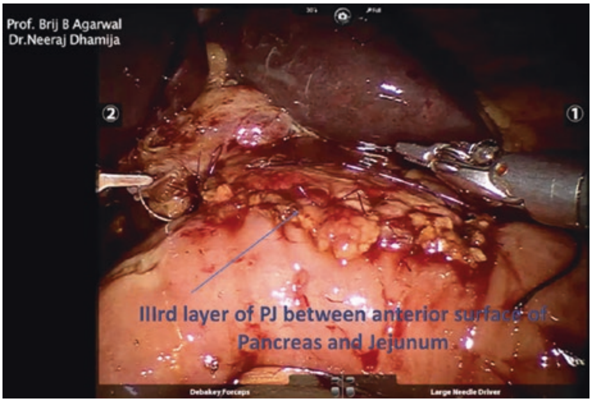

Fig. 8 IIIrd Layer of Pancreatico-Jejunostomy

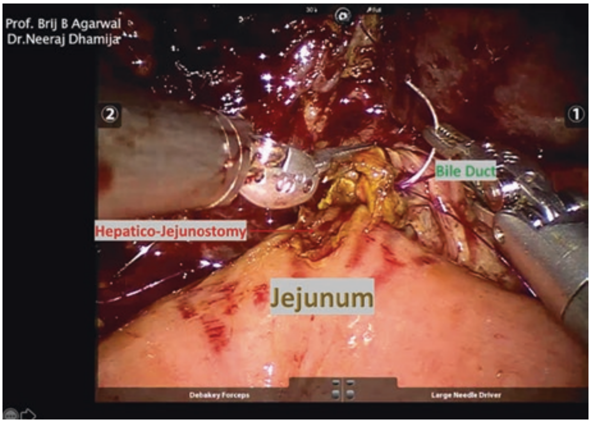

Fig. 9 Hepatico-Jejunostomy

IV. The fourth layer is between the anterior surface of the pancreatic serosa and the sero-muscular layer of the anterior surface of the jejunum. It is done by interrupted 4-0 PDS sutures.

This completes the PJ. The jejunum is then anchored near the bile duct with a 4-0 PDS suture to create a HJ at approximately 10 cm from the PJ.

Hepatico-Jejunostomy [HJ]

An enterotomy is made at the anti-mesenteric border of the jejunum for a length less than the diameter of the bile duct. An interrupted 4-0 PDS sutures are taken starting from the posterior layer of the bile duct followed by the anterior layer [Fig. 9]. Stent or a T-Tube is not placed across the HJ. The jejunum is fixed to the mesenteric window at the transverse colon and the window is closed by 3-0 vicryl sutures.

Undocking of the Robot

After PJ and HJ, the robot is undocked and rest of the procedure is performed by laparoscopic approach.

Gastro-Jejunostomy [GJ]

Approximately 30 cm from the HJ, a GJ is created. It is preferably done with the help of a stapler using a blue reload and 60 mm cartridge. An enterotomy is created at the antimesenteric border of the jejunum and posterior surface of the stomach. An Endo GIA stapler is passed from the enterotomy, one limb in the stomach and another in the jejunum to create the stapled GJ. The enterotomy site is closed with the help of 3-0 PDS suture in a single layer continuous fashion.

After reconstruction, haemostasis is ensured and a 'Stamm type' of feeding jejunostomy is done with a 12 Fr Ryles tube.

Abdominal Drain Placement Is Done at Three Sites

- From left side of the abdomen at the superior surface of the pancreas above the PJ and close to the GJ.
- From right side of the abdomen near the HJ.
- A dependent drain in the pelvis from the right side of the abdomen.

The skin incisions are closed in layers after careful closure of the ports with vicryl no.1 and skin with staplers. Ryles tube is generally not required and if inserted is removed in the post-operative recovery room after full recovery from anesthesia.

Outcomes After RPD/RAPD

Miami guidelines mention about outcome improvement with minimally invasive PD (MIPD) in centers with minimum 20 cases per year [14]. Similarly, after RAPD/RPD statistical improvements are seen in operating time, estimated blood loss, conversion to open, decreasing major complications and postoperative pancreatic fistula occurrences after approximately performing 40 cases (Range 22–80) [15–21]. These high-volume centers have a far better 90day mortality rate compared to low volume centers [22].

RAPD vs RPD has virtually no outcome difference in terms of harvested lymph nodes 13.6 ± 4.0 vs 14.2 ± 5.7 (P-value 0.698), operating time 415.3 ± 89.2 vs 362.4 ± 75.6 min (P value 0.047), estimated blood loss 300 ml [75–500] vs 200 ml [100–400] (P Value 0.439) and blood transfusion requirements (P-value 0.579) [23]. The parietal wound related morbidity is also reduced and this clubbed with an uneventful recovery helps in the early initiation of the adjuvant therapy in a suitable candidate.

Complications of Pancreaticoduodenectomy

The main complications during a robotic pancreaticoduodenectomy surgery are bleeding and it is the most common cause of conversion to the open technique.

The important postoperative complications include:

- Postoperative pancreatic fistula [POPF]
- Post Pancreatectomy Hemorrhage [PPH]
- Delayed Gastric Emptying
- Bile leak/Biliary Fistula/Stenosis
- Anastomotic Leak
- Intraabdominal infection
- Re-laparotomy

Recent reports suggest that after Robotic PD, POPF incidence is only around 10% with high risk factors like soft pancreas and narrow duct ≤2 mm [23]. RPD also shows decreased incidence of delayed gastric emptying (3%) and has better oncologic outcomes in comparison to open PD [24].

Conclusion

Incorporation of the advantages of Robotic Assisted surgery to the complex abdominal surgery can help in implementation of the ERAS protocol. This is advantageous for rapid recovery and discharge from the hospital.

Minimally invasive pancreaticoduodenectomy adds up-to the training of the residents, who after closely watching the anatomy of the complex resection and reconstruction can add rehearsal of the video for better understanding. Cost is an issue for starting and implementation of the robotic pancreaticoduodenectomy program.

Key Clinical Points

1. Gradual increase noted in number of pancreatico-duodenectomies performed by minimally invasive route is mostly due to improved optics and instruments along with reconstruction techniques.
2. Recent meta-analyses have vouched for the safety of robotic pancreaticoduodenectomy with a non-inferior outcome over laparoscopic and open approaches and proposes certain beneficial trends in intraoperative and postoperative parameters.
3. A successful resection and reconstruction by minimally invasive route will add up the advantages of early recovery and discharge from the hospital by limiting the parietal wound morbidity.
4. Post neoadjuvant chemotherapy cases and those requiring vascular resections are no longer a contraindication for RPD.
5. A definite better outcome is seen in obese patients on using the robotic platform.

6. Miami guidelines mention about outcome improvement with MIPD in centers with minimum 20 cases per year. RAPD/RPD improvements are seen in operating time, estimated blood loss, conversion to open, decreasing major complications and postoperative pancreatic fistula occurrences after approximately performing 40 cases.
7. RAPD vs RPD has virtually no outcome difference in terms of harvested lymph nodes, operating time, estimated blood loss and blood transfusion requirements.
8. The main possible complication after RPD/RAPD is bleeding and it is the most common cause of conversion to the open technique during RPD/RAPD.
9. Increased operative time was the most consistent drawback of robotic as compared to open PD, whereas the prominent advantages of robotic approach were less intraoperative blood loss, lower postoperative complications and wound infection rate, earlier hospital discharge rates and a possible improved oncological outcome reflected by increased number of harvested nodes along with a lower margin positivity.
10. Mesopancreas/level 3 dissections in robotic pancreaticoduodenectomy had less blood loss, no delayed gastric emptying and lower chyle leakage.
11. Robotic intracorporeal anastomotic technique has an obvious advantage over laparoscopic approach due to better articulation and higher degree of freedom of instrument movement.

Editor's Note[1]

Pancreaticoduodenectomy was conventionally done by open approaches until lately when rapid evolving techniques of minimally invasive surgery have been transposed into the arena. Recent meta-analyses have vouched for the safety of robotic pancreaticoduodenectomy with a non-inferior outcome over laparoscopic and open approaches and proposes certain beneficial trends in intraoperative and postoperative parameters.

The various types of minimally invasive pancreatoduodenectomy reported in literature are:

I. Laparoscopic assisted
II. Totally laparoscopic
III. Total laparoscopic robotic assisted
IV. Totally robotic.

Minimally invasive versus open pancreaticoduodenectomy: Table EN1 lists the results of various meta-analyses comparing robotic, laparoscopic and open pancreaticoduodenectomy published during the past 5 years.

Table EN1 Meta analyses published on outcome of robotic/minimally invasive and open pancreaticoduodenectomy in past 5 years

Study, author [first], year	No difference	Advantages robotic/ minimally invasive	Disadvantages robotic/ minimally invasive
Perioperative and oncological outcomes following minimally invasive versus open pancreaticoduodenectomy for pancreatic duct adenocarcinoma. Sun R 2021 [1]	• Overall survival • Operative time • Postoperative complications • 30-day mortality • Rate of vein resection • Number of harvested lymph nodes • Rate of positive lymph nodes.	• Disease-free survival • Time to starting adjuvant chemotherapy, • Length of hospital stay • rate of negative margins	
Robotic versus open pancreaticoduodenectomy: a meta-analysis of short-term outcomes. Yan Q 2020 [2]	• Positive margin rate • Lymph nodes harvested • Postoperative complications • Reoperation or readmission mortality rate	• Less blood loss • Hospital stay • Wound infection	Longer operative time

(continued)

[1] References: Main chapter references are included after the "References Editor's Note" section.

Table EN1 (continued)

Study, author [first], year	No difference	Advantages robotic/ minimally invasive	Disadvantages robotic/ minimally invasive
A systematic review and network meta-analysis of different surgical approaches for pancreaticoduodenectomy. Kamarajah SK 2020 [3]	• Major complications • Fistula • biliary leak • mortality • R0 resections.	• Less transfusion • Wound infection • Pulmonary complication • Less hospital stay than open • Lower conversion in total robotic than total laparoscopic group • Higher lymph node yield in total robotic	Operative time for total robotic was longer than open
Robotic-assisted versus open pancreaticoduodenectomy for patients with benign and malignant periampullary disease: a systematic review and meta-analysis of short-term outcomes. Podda M 2020 [4]	• Mortality morbidity • Pancreatic fistula • Delayed gastric emptying hemorrhage • Bile leak • Retrieved lymph nodes • Positive margin status.	• Less blood loss	Longer operative time
Minimally invasive versus open pancreatoduodenectomy-systematic review and meta-analysis. Pędziwiatr M2017 [5]		• Reduced blood loss • Delayed gastric emptying • Decreased length of hospital stay	Longer operative time
Systematic review and meta-analysis of robotic versus open pancreaticoduodenectomy. Peng L 2017 [6]	• Number of lymph nodes harvested; • Operation time; • Reoperation rate; • Delayed gastric emptying, • Bile leakage, • Pancreatic fistula and mortality.	• Less complication, • Margin positivity, • Wound infection, • Hospital stay.	

Table EN1 (continued)

Study, author [first], year	No difference	Advantages robotic/ minimally invasive	Disadvantages robotic/ minimally invasive
Systematic review and updated network meta-analysis comparing open, laparoscopic, and robotic pancreaticoduodenectomy. Aiolfi A 2020 [7]	• Postoperative mortality • Postoperative complications number of retrieved lymph nodes • R0 resection rates.	• Reduced hospital length-of-stay, • Estimated blood loss, • Pulmonary & overall complications • Postoperative bleeding • hospital readmission.	
Minimally Invasive Pancreaticoduodenectomy: What is the Best “Choice”? A Systematic Review and Network Meta-analysis of Non-randomized Comparative Studies. Ricci C 2018 [8]	The TLPD technique was often the worst approach especially for overall and major complications, postoperative bleeding and biliary leak	• Blood loss • Wound infection • Delayed gastric emptying • Length of hospital stay • Harvested lymph nodes • Postoperative morbidity	Operative time and postoperative bleeding,
Safety and efficacy of robot-assisted versus open pancreaticoduodenectomy: a meta-analysis of multiple worldwide centers. Zhang W 2020 [9]	• Lymph node clearance • Postoperative • Pancreatic fistula bile leakage • delayed gastric emptying • 90-day mortality • Severe complications	• Blood loss • Infection rate • Reoperation rate, • Overall complications • Clinical postoperative pancreatic fistula	Operation time
Robotic pancreaticoduodenectomy provides better histopathological outcomes as compared to its open counterpart: a meta-analysis Da Dong X 2021 [10]		• Less blood loss • Less incidence of resection margin involvement. • Higher number of harvested nodes	Operative time
Safety and efficacy for robot-assisted versus open pancreaticoduodenectomy and distal pancreatectomy: A systematic review and meta-analysis. Zhao W 2018 [11]	• Lymph node yield • Rate of pancreatic fistula • Delayed gastric emptying • Reoperation, • Length of hospital stay • Mortality between the two groups.	• Less blood loss • Less wound infection • Lower positive margin rate • Lower overall complications • Faster postoperative off-bed activity	Longer operative time

Increased operative time was the most consistent drawback of robotic as compared to open pancreaticoduodenectomy, whereas the prominent advantages of robotic approach were less intraoperative blood loss, lower postoperative complications and wound infection rate, earlier hospital discharge rates and a possible improved oncological outcome reflected by increased number of harvested nodes along with a lower margin positivity noted in some of the studies [1–11].

Mesopancreatic resection and approach to superior mesenteric artery: A newly emerging concept in pancreaticoduodenectomy is the concept of mesopancreas [level 3] dissection a term akin to mesorectum and mesocolon in colorectal cancers. It is a fascial fusion plane embryologically formed during development of pancreas. It lies posterior to the pancreas and is comprised of pancreaticoduodenal vessels, lymphatics, nerve plexus and loose areolar tissue. Approach to the area is complex due to the complicated anatomy. Reports are emerging on mesopancreatic resection in robotic pancreaticoduodenectomy. A study comparing meso pancreatic resection in open and robotic pancreaticoduodenectomy concluded that mesopancreas/level 3 dissections in robotic pancreaticoduodenectomy had less blood loss, no delayed gastric emptying, and lower chyle leakage. The lymph node yield was higher for mesopancreas/level 3 dissection compared with mesopancreas levels 1 and 2 dissections in the robotic pancreaticoduodenectomy groups. Postoperative complications and mortality were not different due to the additional mesopancreatic excision. Complications, including postoperative pancreatic fistula, delayed gastric emptying, postpancreatectomy hemorrhage, chyle leakage, bile leakage, or wound infection were similar in level 2 vs level 3 dissections of robotic pancreatectomy [12]. Various surgical approaches have been described for approaching the superior mesenteric artery during pancreaticoduodenectomy, viz: anterior, posterior, left and right approach.

Reconstruction after pancreaticoduodenectomy and Pancreaticoeneteric anastomosis: The mode of reconstruction of pancreatico-enteric anastomosis has been a context of debate with some authors preferring a pancreatico-jejunostomy and others opting for a pancreaticogastrostomy. Occlusion of pancreatic duct without anastomosis a method proposed to circumvent the formation of pancreatic fistula has a high morbidity with increased incidence of diabetes noted in such patients and thus not recommended [13]. In a recent metaanalysis comparing pancreaticogastrostomy with pancreatico-jejunostomy it was noted that the pancreaticogastrostomy group had significantly lower incidence in rates of postoperative pancreatic fistulas, intra-abdominal abscesses and length of hospital stay. However, rates of biliary fistula, mortality, morbidity, delayed gastric emptying, reoperation, and bleeding was similar in the two groups [14].

One of the inherent deterrents in minimally invasive gastrointestinal/hepatopancreaticobiliary surgery is the construction of an intracorporeal anastomosis. Robotic anastomotic technique has an obvious advantage over laparoscopic approach due to better articulation and higher degree of freedom of instrument movement. Among different meta-analysis, one such report comparing robotic laparoscopic and open anastomosis in an array of surgical procedures concludes that robotic, laparoscopic and open techniques of anastomosis yielded similar rates of leak and stricture formation [15]. Published meta-analysis on robotic pancreaticoduodenectomy also exhibit a consistent equivalent or lower rate of pancreatic or biliary fistula [Table EN1].

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