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Is the Robotic Assisted Hybrid Approach Increasing the MIS efficiency for Pancreaticoduodenectomy?

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Rezumat

Poate tehnica hibrid-robotică să crească eficiența chirurgiei minim-invazive în duodenopancreatectomie?

Introducere: Duodenopancreatectomia (DP), cunoscută în mod obişnuit ca operația Whipple, este o tehnică chirurgicală complexă utilizată pentru tratamentul diferitelor patologii pancreatice şi periampulare. Pentru a îmbunătăți rezultatele tehnicii tradiționale deschise, s-a făcut pasul firesc către DP minim-invazivă. Cu toate acestea, faza de reconstrucție a fost bariera principală în calea adoptării pe scară largă a tehnicii laparoscopice. Multiple cercetări recente şi studii de caz recomandă tehnica robotică ca mediator pentru timpul de reconstrucție. Propunem o abordare hibridă pentru a îmbina versatilitatea laparoscopiei cu avantajele vizuale şi motorii ale platformei DaVinci Xi, în vederea maximizării preciziei din timpul de reconstrucție. Sugestia noastră se bazează pe experiența instituțională pe care am avut-o cu standardizarea diferitelor proceduri şi protocoale chirurgicale.

Metode: Acest studiu este axat pe rezultatele DP asistate robotic în instituția noastră. Unsprezece pacienți au fost operați prin această tehnică între 1 ianuarie 2020 şi 7 martie 2023 (N=11). Au fost implicate două abordări ale operației: DP-hibrid tip A (N=6) şi DP-hibrid tip B (N=5).

Rezultate: Dintre cei unsprezece pacienți care au suferit DP-hibrid, cei mai mulți dintre ei au fost bărbați (81,8%) cu o vârstă medie de 61,9 ani (interval 45-75 de ani). Durata medie a intervenției a fost de 618 minute (interval 480 până la 780 minute). Pierderea medie de sânge a fost de 159 ml (interval între 50 şi 350 ml). Au fost efectuate zece operații pentru malignitate şi una pentru tumoră duodenală neuroendocrină; numărul mediu de ganglioni limfatici extraşi a fost de 16,2 (interval de la 11 la 24 de ganglioni) şi toate piesele de rezectie au fost raportate ca R0. Durata medie de

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internare a fost de 18 zile (interval de la 8 la 40 de zile). Au fost necesare reintervenții in cazul a cinci pacienți (N=5), toți din grupul de tip A. Nu au existat conversii la intervenția chirurgicală deschisă în timpul procedurilor initiale. De asemenea, nu s-au detectat fistule pancreatice post-operatorii cu răsunet clinic. Mortalitatea la treizeci de zile a fost 0, cu o mortalitate la 90 de zile prin embolie pulmonară masivă.
Concluzii: Abordarea hibridă îmbină avantajele celor două tehnici minim invazive: laparoscopică şi robotică. În timp ce laparoscopia este mai facilă în manipularea intestinului şi permite reconstrucția Roux en Y şi anastomoza gastro-pancreatică, platforma robotică permite chirurgului să efectueze delicatele anastomoze pancreatice cu o precizie ridicată. Cel mai important element al curbei de învățare este standardizarea tehnicii şi selecția atentă a pacienților.

Cuvinte cheie: duodenopancreatectomie, miniminvaziv, asistat robotic, hibrid, laparoscopie

Abstract
Introduction: Pancreaticoduodenectomy, commonly known as the Whipple procedure, is a complex surgical technique employed for the treatment of various pancreatic and periampullary pathologies. Minimally invasive PD was created in an attempt to enhance the outcomes of the traditional, open technique. However, the reconstruction phase has been recognized as a substantial barrier to widespread adoption of the laparoscopic technique. Several research appraisals and case studies recommend the robotic technique as a facilitator during the reconstruction steps. We propose a hybrid approach to combine the versatility of laparoscopy and the visual and motor advantages of the DaVinci Xi in order to maximize the precision of the reconstruction. Our suggestion is based on the experience that our institution has had with the standardization of different surgical procedures and protocols.
Methods: This article is focused on the outcomes of robotic assisted PD in our institution. Eleven patients underwent robotic assisted laparoscopic PD between 1st January, 2020 and 7th March, 2023 (N=11). There were two approaches involved: hybrid PD type A (N=6) and hybrid PD type B (N=5).
Results: Of the eleven patients who underwent hybrid PD, most of them were men (81.8%) and mean age was 61.9 years-old (range 45 to 75 years). The mean operative duration was 618 minutes (range 480 to 780 minutes). Mean blood loss was 159 mL (range 50 to 350 mL). Ten operations were performed for malignancy and one for neuroendocrine duodenal tumour; the mean number of lymph nodes retrieved was 16.2 (range 11 to 24 nodes) and all the specimens were reported by pathology as R0. Mean hospital stay was 18 days (range 8 to 40 days). Reoperations were necessary in five patients (N=5), all from the type A group, and mortality occurred in one (N=1) patient. There were no conversions to open surgery during the index procedures as well as no clinically relevant postoperative pancreatic fistulae. Thirty-day mortality was nil, with 1 mortality at 90-days due to massive pulmonary embolism.
Conclusions: The hybrid approach facilitates the advantages of both laparoscopic and robotic approaches. While laparoscopy is safer in manipulating the bowel and allows the Roux en Y reconstruction and gastro-pancreatic anastomosis, the robotic assistance enables the surgeon to perform delicate anastomosis with a high accuracy. The learning curve's most important element is standardization and careful patient selection along with a stepwise approach.

Key words: pancreaticoduodenectomy, minimal-invasive, robotic-assisted, hybrid, laparoscopy

Introduction

In the realm of pancreatic surgery, pancreaticoduodenectomy (PD) stands as a vital procedure for treating neoplastic lesions of the periampullary region and the pancreatic head. It is often regarded as the only treatment available for hepatobiliary disorders such as pancreatic head tumors, malignant periampullary tumors, DI/DII cancer, as well as distal cholangiocarcinoma (1). However, due to its retroperitoneal position, nearby major vessels, and delicate repair, it is a challenging procedure with substantial perioperative morbidity and mortality (2,3). While high-volume referral centers have successfully reduced the perioperative mortality rate of PD to less than 5%, major morbidity remains a significant concern, with morbidity rates ranging from 30% to 40% (3-5). To address these challenges, minimally invasive surgical (MIS) approaches were applied to pancreatic surgery (6-8). Also, the concept of surgical oncotaxis has emerged, suggesting that minimizing surgical stress can enhance the immune response and impede tumor progression (9).

The advent of laparoscopic surgery marked a significant milestone, with the first laparoscopic PD being reported in 1994 (6). However, initial advancements in laparoscopic surgery primarily focused on distal pancreatectomy (DP), which is technically less demanding than PD (10). Nonetheless, the technical complexity of laparoscopic PD presented significant obstacles to widespread adoption among pancreatic surgeons. Challenges such as restricted instrument motion, poor surgeon ergonomics, and a steep learning curve hindered radical oncological dissection and the performance of critical anastomoses (9-11).

In recent years, the da Vinci Robotic Surgical System has gained recognition and acceptance in the field of pancreatic surgery (4,10,12,13). Robotic surgery offers several advantages, including improved ergonomics, high-definition 3D magnified view, and increased range of motion with EndoWrist® instruments which restore hand-eye coordination (3,11,13,14). The first robotic PD was reported in 2001 (8), and subsequent studies have compared its outcomes to those of laparoscopic PD and open (3,7,15,16). Robotic PD has demonstrated comparable complication rates and similar oncological outcomes when compared open and laparoscopic PD with the advantages of a reduced blood loss and a shorter postoperative stay (12,14,17,18). In the published literature, the incidence of pancreatic fistula (PF) after robotic PD is inconsistent (7,19). However, operative times tend to be longer for the robotic procedure, as they are for both laparoscopic and open PD (20).

Despite the promising outcomes of robotic PD, surgeons remain cautious about the technical challenges and extensive learning curve associated with the procedure. Moreover, the lengthy duration of operation, as well as the cost-effectiveness of surgery, are key concerns taken into account (11,12).

To address this, a hybrid laparoscopic with robotic-assisted approach has been proposed as a safer alternative (10,19,20) This method combines the advantages of traditional laparoscopy, such as rapid instrument movement and exchange, and easy access to all four quadrants of the abdomen, with the stability, articulated instruments, and excellent visualization provided by the robotic system for specific steps of PD (1,8,9,21,22). By utilizing laparoscopy for resection phases and then employing the robotic platform for reconstruction, this hybrid method bridges the expertise gap required to perform pancreatico-enteric anastomosis laparoscopically (22).

We have looked with great interest to the hybrid PD approach and introduced it in our practice in 2020. Since then, all the technical aspects and the added modifications to the surgical protocol of the hybrid-PD technique were carefully recorded.

The aim of our study is to describe the technical protocol of hybrid-PD and to analyze the outcomes and efficiency of this approach.

Method

All the consecutive patients who underwent hybrid-PD between 1st January, 2020 and 7th March, 2023 are included in this study in this

single center, single surgeon study. The prospectively held institutional database was examined retrospectively. Data was collected from clinical and operative records, including video footage. Conversions to open surgery or patients with positive dissemination following initial laparoscopy and intraoperative ultrasonography were excluded.

All the patients underwent extensive preoperative investigations and were discussed during institutional Tumor Board meetings, receiving the recommendation for surgery. The cases with documented vascular involvement and systemic dissemination were referred for other oncological therapies.

This study was carried out in accordance with the policies established by Ponderas Academic Hospital's institutional review board. After emphasizing the benefits and limits of the robotic assisted technique, including expenses, the patients granted informed consent.

In this study, we measured the total length of the procedure, blood loss, number of lymph nodes harvested, hospital length of stay and complications - postoperative pancreatic fistula (POPF), bleeding, reinterventions. We have not carried out a cost assessment yet.

Statistical Analysis

Statistical analysis was performed using Microsoft® Excel 2021 and Jamovi Stats v 2.3.26. Unpaired t test was used to measure if there are any statistical differences between findings in type A and type B groups. A p-value of < 0.05 was considered statistically significant.

Surgical Technique

All the procedures were performed under general anesthesia with oro-tracheal intubation. The patient is placed in a supine position, with the legs parted ("French position"). The table is placed in a reverse Trendelenburg position at 15-20 degrees angle.

There were two technical strategies we have used in this study, specifically named: Hybrid PD type A later modified to Hybrid PD Type B. The surgical steps of the two surgical protocols are described below, and their results are compared.

Hybrid-PD type A

The surgical procedure follows a comprehensive laparoscopy-robotic-laparoscopy (LAP-ROB-LAP) approach.

CO2 is insufflated using a Veress needle inserted into the Palmer's point. A 10 mm reusable optical trocar is blindly introduced above the umbilicus, to facilitate the initial inspection using a 42cm long 45º endoscope (KARL STORZ, Germany). Working trocars of 5 or 12 mm are placed under direct vision to perform the adhesiolysis, in patients with previous abdominal surgery and, to manipulate the fat infiltrated viscera in patients with central obesity. A 10 mm liver Cuschieri retractor (KARL STORZ, Germany) is introduced through a 10 mm Ternamian trocar placed in the left hypochondrium. These steps are facilitating the complete evaluation of the entire peritoneal cavity, including, and focusing to the peri-pancreatic area.

Peritoneal lavage sampling for cytology and intraoperative laparoscopic sonography (*Fig. 1*) are included in our routine institutional protocol for MIS oncological procedures.

During this operative step, the presence of local or regional dissemination can be demonstrated in patients with preoperative negative radiology for metastatic disease. In this scenario, chemotherapy and not surgery will be the option in those patients.

According to our protocol of Hybrid PD, laparoscopy is used for the mobilization of the hepatic flexure of the colon, and, by the dividing of the gastro-colic and gastro-hepatic ligaments getting access to lesser ommentum. This is followed by the mobilization of the stomach up to its distal half and its subsequent transection using linear staplers, which unveils the anterior surface of the pancreas and duodenum.

To further facilitate the procedure, a Kocher maneuver is performed to mobilize the duodenum from right to left. To perform this surgical step, an optical trocar is placed on the

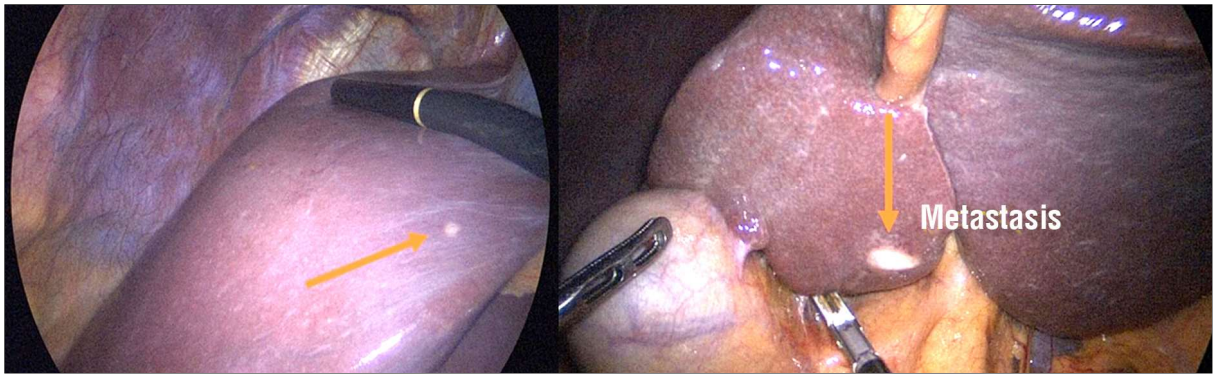

Figure 1. Intraoperative ultrasound during Hybrid PD. The presence of histologically proven metastatic disease (arrows) will limit the procedure to a palliative one.

right anterior axillary line, while the surgeon and the cameraman are placed on the right side of the patient. Two additional 5 mm cannulas are necessary to extensively perform the retro duodeno-pancreatic dissection until it reaches the inferior mesenteric vein (IMV). A cotton gauze is left in place and the surgeon moves back between the patient's legs, while the endoscope is introduced through the umbilical port. The omentum is carefully lifted using Croce-Olmi® double fenestrated forceps (Karl STORZ, Germany), being aware that often it is very heavy due to the excessive omental fat. The dissection continues at the Treitz angle using 5 mm energy devices: monopolar scissors and bipolar devices (LigaSure, Medtronic, US), to circumferentially free the jejuno-duodenal angle from left to right. The jejunum is divided at 5 cm from the duodenum using a 60mm white linear stapler and left on the specimen. Once the duodenum is successfully uncrossed, the proximal end of the jejunum is passed through the transverse colon mesentery, anchored to the stomach, ready for the gastro-jejunostomy.

A 40 cmc Roux limb is created for the biliary and pancreatic anastomosis, and its' proximal end is placed through and above the right mesocolon, easy to be accessed for the robotic reconstruction step. A side-to-side jejuno-jejuno-anastomosis (JJA) is performed using white linear stapler and 3.0 Prolene (Ethicon, US), assuring a 40cm alimentary limb.

Subsequently, the surgical team continues the laparoscopic steps with meticulous dissection of the gastro-duodenal artery and main bile duct which are divided using 30 mm vascular staplers. *Fig. 2 A,B.* Then, hook electrode is used for freeing the superior and

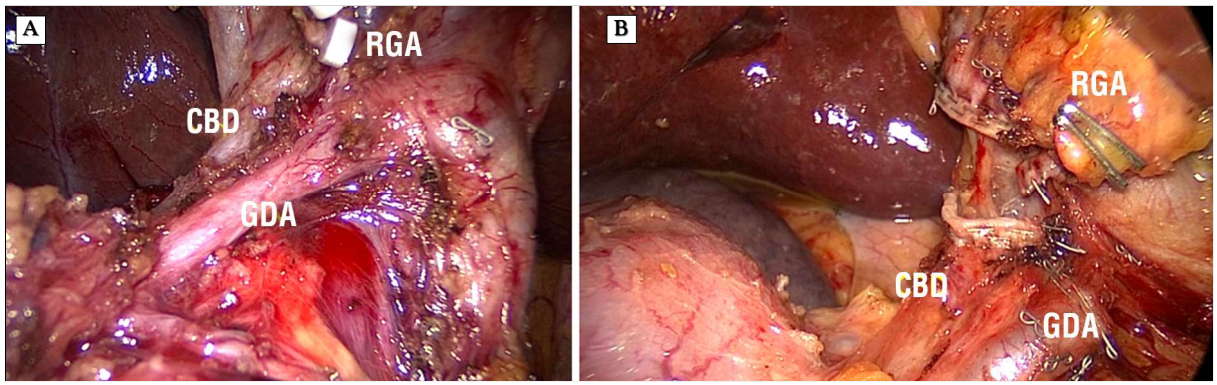

Figure 2. Hybrid PD **(A)** GDA and main bile duct are dissected. RGA is divided. **(B)** GDA and CBD are divided. (GDA: gastroduodenal artery; CBD: common bile duct; RGA: right gastric artery)

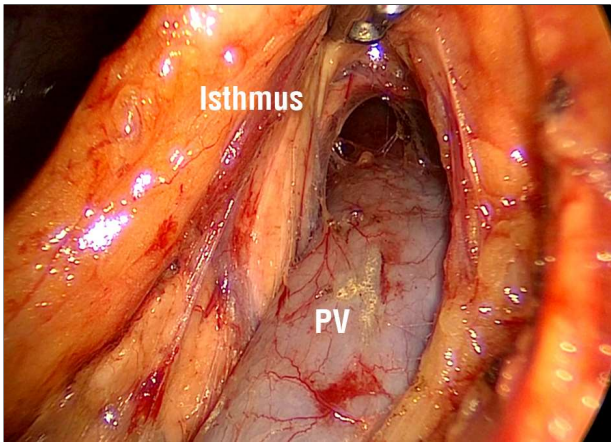

Figure 3. Tunneling in an avascular plane below the pancreatic isthmus and above the superior mesenteric and portal vein. (PV: portal vein.)

inferior border of the pancreas and, following cranially the mesenteric vein, the dissection continues in the retro pancreatic space between the isthmus from the portal vein (*Fig. 3*).

At this stage, the DaVinci Xi robotic surgical system is introduced. Robotic assisted monopolar scissors is used to divide the pancreas. The pancreatic duct is identified, and a thin catheter is introduced in it.

The dissection continues using monopolar scissors, bipolar forceps, and the vessel sealer® (Intuitive, US). The uncinate process is mobilized, the gastro-duodenal vein and Belcher vein are clipped and divided, and the robotic assisted dissection completes the liberation of the pancreatic head. The specimen is introduced into an EndoBag and parked in the left abdominal upper quadrant.

Proceeding further, the proximal end of the Roux limb is placed next to the pancreas and, a robotic assisted pancreatico-jejunostomy is performed using interrupted 5.0 Prolene sutures, with the prior introduction of a 6-Fr Catheter through the pancreatic duct and jejunum. To enhance the anastomosis, four 2.0 braided absorbable interrupted sutures are employed, primarily to secure the pancreatic body to the jejunum. The subsequent critical step entails the end-to-side robotic-assisted choledoco-jejunostomy, which is conducted using 4.0 interrupted PDO sutures guided by a 10-Fr silicone catheter.

Cholecystectomy and near-to-red indocyanine green (ICG) angiography are the last maneuvers of the robotic step. The DaVinci Platform is undocked, and the procedure continues by laparoscopic means. The specimen is removed via a Pfannenstiel suprapubic incision. The end-to-side gastro-jejuno-anastomosis (GJA) is performed using a 60 mm TAN linear stapler (Tristaple, Medtronic, US) and 3.0 Prolene (Ethicon, US). Care is taken that the GJA is placed below the mesocolon, and all the mesenteric gaps are closed with non-resorbable monofilament thread.

Lastly, the laparoscopic component of the procedure concludes with a comprehensive inspection and appropriate drainage placement.

Hybrid-PD type B

The above-described surgical protocol for Hybrid PD (type A) was applied for the first six patients in this series. Aiming to improve the operational efficiency and reducing the total surgical time, the approach's sequence LAP-ROB-LAP was later modified to laparoscopic-robotic (LAP-ROB) identified as Hybrid PD Type B. In other words, the robotic-assisted approach was mainly used for the reconstruction step, during the second part of the procedure.

The surgical strategy for Hybrid PD Type B consists of similar steps as for Type A, until the dissection of the pancreatic isthmus to the portal vein is performed. At this point, the resection step is laparoscopically continued using monopolar electrode, LigaSure (Medtronic, US), ML hemostatic clips, RoBi® Kelly Bipolar forceps (Karl STORZ, Germany), and efficient aspiration. Furthermore, we have noticed a better correlation of the surgical team by involving two aid surgeons providing an improved operative field exposure and efficiency for dissection.

The specimen is introduced into an Endobag and extracted through a suprapubic laparotomy, closed immediately after (*Fig. 4*).

A laparoscopic Roux en Y end-to-side gastro-jejunostomy is performed as described before (*Fig. 5*). A naso-gastro-jejunal tube

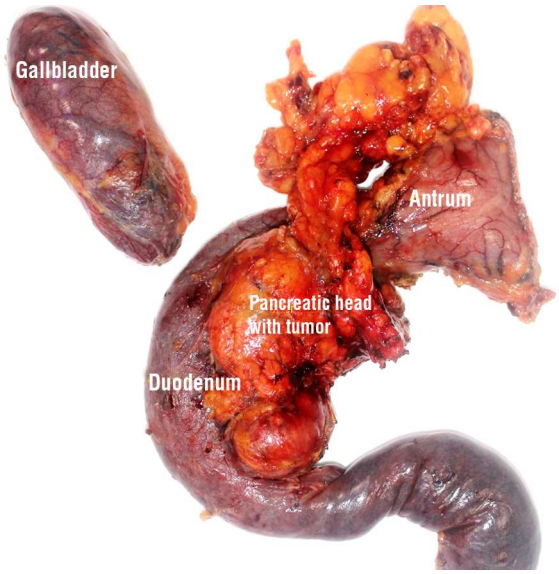

Figure 4. En-bloc Hybrid-PD specimen consisting of: gastric antrum, pancreatic head with tumor, duodenum and gallbladder.

is endoluminally passed to the JJA. The mesenteric gaps are closed, and the proximal end of the bilio-pancreatic loop is passed through the right mesocolon, anchored nearby (*Fig. 6*). Fundus-first cholecystectomy is performed as the last gesture of the laparoscopic step.

At this stage, the DaVinci Robotic platform is docked to perform the robotic-assisted pancreatic and biliary jejunal anastomosis, following the technical protocols described for Hybrid PD Type A (*Figs. 7, 8*).

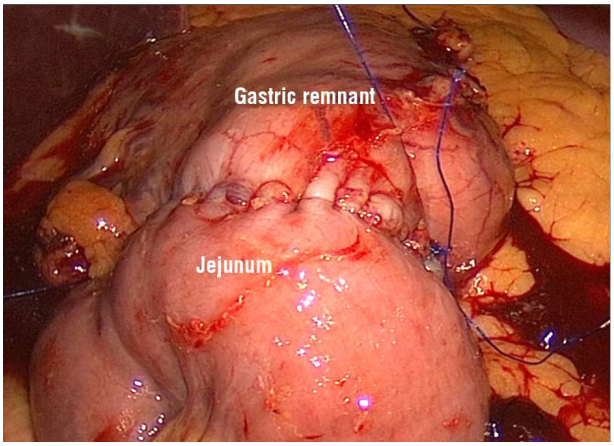

Figure 5. Gastro-jejunostomy

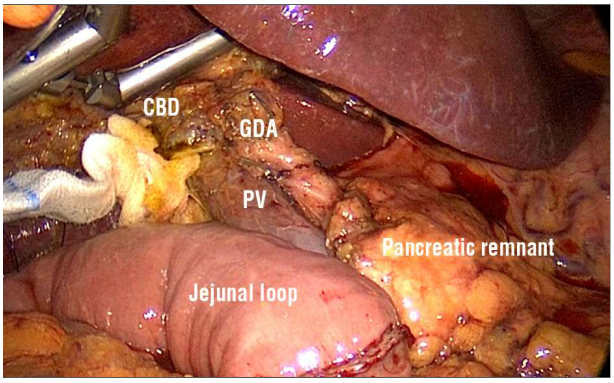

Figure 6. The Roux jejunal loop is prepared for the robotic reconstruction. The divided CBD and GDA can be seen. PV, portal vein; CBD, common bile duct; GDA, gastroduodenal artery.

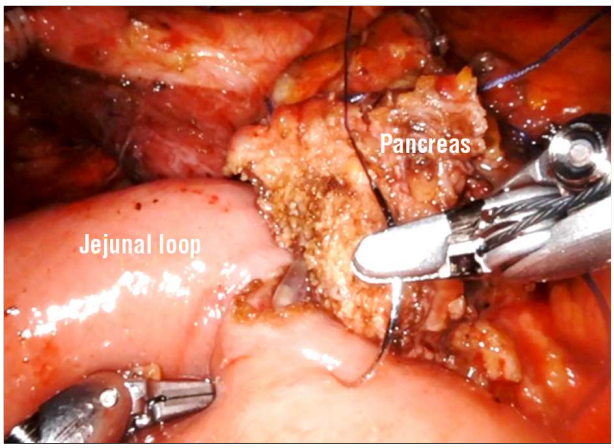

Figure 7. Robotic duct-to-mucosa pancreatico-jejunostomy using 5.0 resorbable stiches

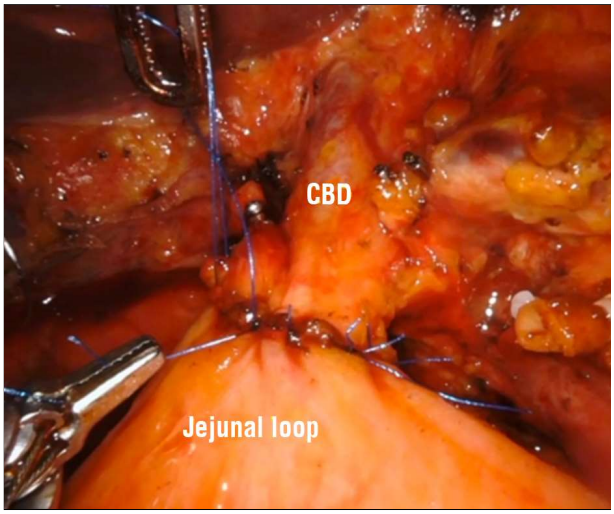

Figure 8. Robotic-assisted choledoco-jejunostomy using 4.0 resorbable stiches . (CBD: common bile duct).

As a technical variant for Hybrid PD Type B, in case the gastro-pancreatic anastomosis (GPA) is decided, its' performance is done before the robotic platform is docked (*Fig. 9 A*). This is the preferred option for high-risk pancreatic parenchyma (23,24). The pancreatic stump needs to be freed for at least 4-5 cm. Any branch of the splenic vessels is divided between sutures, allowing mobilization of pancreatic stump. Under robotic assistance the ICG check (FireFly®, Intuitive, US) (*Fig. 9 B, C*) and the closing of the anterior gastric wall are later performed.

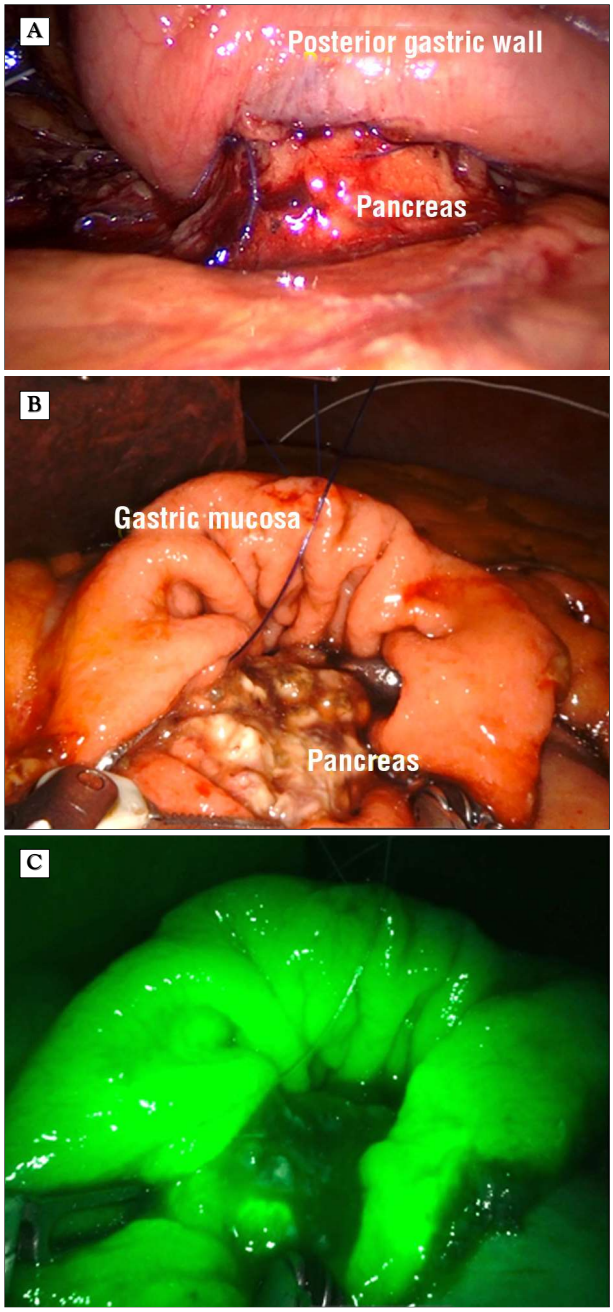

Figure 9. Hybrid PD: Gastro-pancreatic anastomosis **(A)** laparoscopic aspect. **(B)** robotic intragastric aspect before closing the anterior gastrotomy. **(C)** ICG verification using robotic technology (Firefly®)

Results

Thirteen patients received the Tumor Board recommendation for surgery. Two patients had local dissemination demonstrated at the initial laparoscopic and intraoperative US evaluation, thus being excluded from the current analysis.

A total of eleven patients underwent hybrid pancreaticoduodenectomy (PD) in this study. The majority of the patients were men, accounting for 81.8% of the cohort. The mean age of the patients was 61.9 years, ranging from 45 to 75 years.

Indications for surgery were: tubulo-villous adenoma of the vaterian ampulla (N=1), choledochal mucinous adenocarcinoma (N=1), vaterian ampulloma (N=2), metastasis from clear cell renal cell carcinoma to pancreatic head (N=1), duodenal neuroendocrine tumor (N=1), pancreatic ductal adenocarcinoma (N=4) and duodenal mucinous adenocarcinoma (N=1).

The operative duration for the hybrid PD procedure had a mean of 618 minutes, with a range of 480 to 780 minutes (*Table 1*). The

	Operation Time (minutes)	BL (ml)	No. of harvested nodes	LOS (days)
N	11	11	11	11
Mean	618	159	16,2	18,0
Median	600	100	15	14
Standard deviation	113	109	4.12	11.6
Minimum	480	50	11	8
Maximum	780	350	24	40

Table 1. Hybrid-PD operative results. BL: blood loss; LOS: length of stay.

Table 2. Early outcomes for hybrid-PD type A and type B. Unpaired t-test was used to calculate statistical significance. No difference was recorded between the two groups.

	Operation Time (minutes)		Blood loss (mL)	
	Type A	**Type B**	**Type A**	**Type B**
N	**6**	**5**	**6**	**5**
Mean	595	645	175	140
Median	570	720	175	100
Standard deviation	121	109	104	124
Min	480	480	50	50
Max	780	720	300	350
P value	0.4940		0.6223	

mean operative time was increased by 50 minutes in Type B hybrid-PD from 595 minutes to 645 minutes (*Table 2*). Throughout the surgeries, the mean blood loss was 159 mL, ranging from 50 to 350 mL, with a decrease in the type-B cohort (Mean=140 ml vs 175 mL for type-A). Out of the eleven operations performed, ten were for malignancies, while one was for a neuroendocrine duodenal tumor. There were no conversions to open surgery at index procedure.

The mean number of lymph nodes retrieved during the surgeries was 16.2, with a range of 11 to 24 nodes. Importantly, all the surgical specimens were reported as R0, indicating complete resection of the tumors.

The mean hospital stay for the patients was 18 days, with a range of 8 to 40 days. We have not encountered any case of clinically relevant postoperative pancreatic fistula.

However, it is worth noting that reoperations were required in five patients (*Table 3*). Specific interventions included laparoscopic drainage of a subphrenic abscess in one case, laparoscopic drainage of a low debit biliary fistula in another case, and two patients who required laparoscopic hemostasis from bleeding from the gastro-duodenal artery (GDA) stump. One of these two patients had to be converted to open surgery. Additionally, hemostasis by open surgery was performed in another patient experiencing hemorrhagic shock from bleeding from the pancreatic body near the pancreatico-jejunostomy.

Table 3. Data regarding re-operations. Five patients, all from type A hybrid-PD group, required reintervention.

	Duration of re-operation	No of days from index procedure
N	5	5
Mean	166	8.00
Median	150	10
Standard deviation	90.2	4.30
Minimum	60	2
Maximum	275	12

Complications that required reoperations occurred in patients who benefited from Type A hybrid-PD (5 out of 6 patients). Re-operations were required between postoperative day 2 and 12 (mean of 8 days) and their mean duration was 166 minutes (range 60-275 minutes).

Thirty-day mortality was nil, while the 90-day mortality was encountered one case due to massive PE.

Discussions

Pancreaticoduodenectomy presents significant technical challenges in abdominal surgery. The elaborate dissection and the need for multiple anastomoses make this procedure inherently difficult, even when performed through an open approach (13). However, the introduction of robotic surgery and endoscopic equipment has revolutionized pancreatic surgery, following a similar trajectory as minimally invasive prostatectomy (9). Robotic assistance has acted as a catalyst for surgeons who were previously hesitant to operate using conventional laparoscopic techniques.

Robotic surgery addresses several critical limitations of traditional laparoscopy, including monocular vision, restricted degrees of freedom, and the challenges posed by pivot

and fulcrum effects, especially in mastering suturing techniques (22,25). In contrast, the robotic approach provides surgeons with a three-dimensional stereoscopic view of the surgical field, restoring hand-eye coordination. The Endowrist® instrumentation replicates human hand movements with seven degrees of freedom and eliminates hand tremors. In the case of PD, these advantages, particularly the capabilities of the articulated arm, make it feasible to perform secure duct-to-mucosa anastomoses (10,15).

While some studies caution against routine laparoscopic PD due to the associated post-operative pancreatic fistula (POPF) which can lead to high morbidity and mortality rates (7), the choice between laparoscopic and robotic hybrid PD depends on the merits and drawbacks of each technique.

Laparoscopic surgery offers quicker operator movements and instrument changes, enabling prompt response to intra-operative difficulties such as bleeding (16). The range of motion for both the operator and assistant is also wider, which proves beneficial given the wide surgical field and deep abdominal location of the dissection phase in PD (19,20). On the other hand, robotic surgery excels in providing a fixed field and fine movement required during the anastomosis phase, making it more suitable for this specific aspect of the procedure (4,26). The main limitations of the existing robotic system include the absence of tactile feedback, the potential for system errors, the risk of arm collisions, the inability to readjust the patient once the robot is connected, and the difficulty of exchanging surgical instruments, which can interrupt the smooth progress of the operation (1,2,13,27).

In light of these considerations, a hybrid approach, utilizing both laparoscopic and robotic techniques, materializes as a valuable strategy for performing minimally invasive PD (19). This hybrid surgery effectively overcomes the limitations of each approach, combining the advantages of laparoscopic surgery's quick movements and instrument changes with the robotic system's precision in performing the anastomosis. By leveraging the strengths of both techniques, surgeons can optimize the outcomes of MIS-PD and traverse the challenges posed by this complex procedure. According to certain reports, robotic surgery makes it possible for surgeons to execute PD with a shorter learning curve and a lower conversion rate (3).

Literature in the field supports the findings from our cohort. Previous studies have also reported a higher proportion of male patients undergoing PD (5) The mean age of 61.9 years aligns with the typical age range of patients diagnosed with pancreatic diseases (28). The average operative duration of 618 minutes is consistent with the time required for hybrid PD, as robotic-assisted PD is known to have a longer operative time compared to traditional open or laparoscopic approaches due to the additional time required for docking the robot, setup, and learning curve (2,3,11). The range of operative duration reported in your study (480 to 780 minutes) is also within the expected range for robotic-assisted PD (20,25). We recorded a longer operative time for type B hybrid-PD which may be the result of an extensive use of the robotic platform and less steps via laparoscopy. Also, in one case there was an extensive adhesiolysis prior to resection and one patient had Grade III obesity (BMI of 41 kg/m2) which added to de difficulty of the procedure. The mean of a 50-minute difference is not statistically significant ($p= 0.49$).

All resections were reported as R0, indicating complete resection of the tumors which is in line with the current statements that oncological outcomes are similar between open and minimally invasive surgery (17,18).

The mean number of lymph nodes retrieved (16.2) is in conformity with the recommended minimum of 15 lymph nodes to accurately stage the disease and assess prognosis (29).

Five out of the six patients who had Type A Hybrid PD experienced complications that required additional surgery, which may not be amendable to the method itself but rather the intrinsic complications that occur during the

learning curve.

The pancreatic fistula is responsible for the majority of the morbidity associated with PD (14,21,30). Current research has indicated that the utilization of a surgical microscope may result in a reduction in the occurrence of pancreatic fistula (31). Despite the steep learning curve, there were no clinically relevant POPF encountered in 11 hybrid PDs. The robotic platform provides a stereoscopic high-definition view with image magnification of up to fifteen times, tremor filtration, and scaled motion that is ideal for the reconstruction phase.

After a Whipple procedure, the postoperative complication that poses the greatest threat to a patient's health is delayed bleeding (5,32). Indeed, two of the five re-operations where due to blood loss from the GDA stump (one case) and from the pancreatic body near the pancreatico-jejunostomy in another.

The effect of recent improvements in critical care, which have dramatically improved postoperative outcomes with lower mortality, should be taken into account when interpreting these complications (1). This complex surgery with complex patients that needs integrated ICU, surgical and medical care to deal not only with index procedure, but with complications as well. This is why these procedures should be carried out in centers of excellence (5,17).

There were no conversions during index procedure, despite having some patients with high BMI, local modified anatomy (previous pancreatitis, previous biliary stents) or difficult adhesions. This may be related to a more exact dissection in confined places, increased ergonomics, enhanced stability and clearly defined 3D anatomical planes of dissection brought by the hybrid approach.

Our research has some limitations. For instance, because the technique was highly specialized and new to our institution, the case volume was low with a heterogenous group. Also, the present study is a retrospective, small sized cohort analyses and we have not performed a cost analysis yet. Another limitation of our study is that, no comparison of the hybrid PD initial results with the full robotic PD approach was performed.

This study contributes to the scarce literature in terms of hybrid – laparoscopic and robotic – PD as there are only a few studies so far (19,33–35). We consider this technique efficient, and it can be reproduced in centers who have advanced minimally invasive facilities as well as experienced teams that can deal with inherent complications. We assume that this expensive procedure is balanced by the benefits to the patient (lower morbidity, shorter hospital stays, quicker return to activity). We will address cost-effectiveness in further studies.

This would open doors to enrolling more patients with an indication for PD. Large scale studies (multicentric or RCTs) are necessary to demonstrate the long-term benefits of hybrid-PD

However, more trials may argue for the best sequence of laparoscopic and robotic assisted steps while large scale studies (multicentric or RCTs) are necessary to demonstrate the long-term benefits of hybrid-PD.

Conclusions

The technical aspects of the hybrid PD approach were described underling the benefit of laparoscopic versatility in the resection phase and the precision of the reconstruction phase via robotic platform in our initial experience. The efficiency of this approach has to be further demonstrated expected to facilitate the introduction of MIS-PD into a larger number of pancreatic surgery centers.

Conflicts of Interests

The authors have no conflict of interest.

Financial Disclosure

The authors have no financial disclosures.

Ethical Statement

All procedures performed were in accordance

with the ethical standards of the 1964 Helsinki Declaration and its later amendments. Informed consent was obtained.

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