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Pancreatic Anastomosis in Robotic-Assisted Pancreaticoduodenectomy: Different Surgical Techniques

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Keywords

Robotic surgical procedures · Pancreaticoduodenectomy · Pancreaticojejunostomy · Pancreogastrostomy surgical technique · Minimally invasive surgical procedures

Abstract

Robot-assisted pancreatoduodenectomy (R-PD) may provide challenges but potential benefits for pancreatic-enteric anastomosis fashioning. Despite numerous trials comparing different pancreatic-enteric anastomosis techniques, an ideal method is still missing. This study aims to describe different management strategies and surgical techniques of standardized pancreatic-enteric anastomoses during an R-PD. This study reported the robotic technical steps of the modified end-to-side Blumgart pancreaticojejunostomy, the Cattel-Warren duct-to-mucosa pancreatojejunostomy, with internal or external pancreatic duct stent, and the modified end-to-side, double-layer pancreogastrostomy. A dual-console da Vinci Xi Surgical System® (Intuitive Surgical Xi, Sunnyvale, CA) was used to perform all the R-PD. Different robotic pancreatic-enteric anastomosis techniques can be used during the reconstruction phase, possibly reproducing the open technique. The type of anastomosis and applied mitigation strategies should balance surgical strategy adaptability and operative technique standardization. R-PD should be performed in high-volume centers by surgeons with extensive experience in pancreatic and advanced MI surgery, enabling different but standardized anastomotic techniques based on patients' risk factors and intraoperative findings. Future studies on robotic pancreatic anastomosis should focus on personalized approaches after adequate risk stratification.

Introduction

Pancreaticoduodenectomy is considered the most challenging abdominal surgical procedure due to extensive anatomical dissections and the complexity of continuity reconstruction [1]. These peculiarities have initially hindered minimally invasive (MI) approaches, but the advent of robotic-assisted surgery has partially exceeded some of the limitations of the laparoscopic technique [2, 3], allowing its gradual adoption for pancreatic head resections [2, 4]. As a result, robotic-assisted pancreaticoduodenectomy (R-PD) is now recognized as a safe and feasible approach for selected patients in many high-volume centers worldwide [5].

Robotic systems provide surgeons with a stable and immersive view of the surgical field with a high 3D

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definition, increase surgical precision by filtering out physiological tremors, and offer extra degrees of movement, providing tremendous potential benefits for pancreatic-enteric anastomosis fashioning [6]. However, it is still unclear whether such an enhanced surgical technique can be superior in preventing postoperative morbidity, especially a postoperative pancreatic fistula (POPF) [7].

Many trials and meta-analyses have failed to identify a superior or ideal method of pancreatic-enteric anastomosis once performed through an open approach [8], but the advantages offered by the robotic technology could question the evidence achieved. This study aims to critically describe different management of the pancreatic remnant and the surgical technique of three pancreatic-enteric anastomoses performed during an R-PD.

Methods

Data of three exemplary patients submitted to R-PD in 2020 at the Verona University Hospital were retrieved from a prospectively maintained database. The Institutional Review Board's approval for data collection and analysis was obtained (1101CESC). Written informed consent was collected from all patients.

All R-PDs were performed with a dual-console da Vinci Xi Surgical System® (Intuitive Surgical Xi, Sunnyvale, CA) with two operating surgeons and at least one bedside assistant. Indications for R-PD were pancreatic peri-ampullary lesions, as vascular and multi-organ involvement (assessed at preoperative imaging), body mass index >35 kg/m^2, chronic pancreatitis, and a pancreatic mass greater than 5 cm contraindicated the robotic approach according to Institutional policies. Stent placement was intraoperatively considered once the pancreatic fistula risk was assessed in patient with small main pancreatic duct and soft texture.

Postoperative outcomes of interest included major complications, defined as Clavien-Dindo grade higher than grade II, and pancreas-specific complications, such as POPF and its risk prediction were collected and classified according to international definitions [9, 10]. The postoperative management of surgical drains followed a selective placement and early removal policy as previously described [11].

Surgical Procedures

Operative Setting

The patient was placed in a French position, in reverse Trendelenburg, by 20–30°. The pneumoperitoneum was created by introducing the first robotic port (8 mm) at the umbilicus level through an open technique and insufflating to 12 mm Hg CO2 pressure. The other robotic ports were placed – two ports on the right, one at the midclavicular line and the other at the anterior axillary line, and one in the left midclavicular line. The distance between the trocars was approximately 7–8 cm. The robot was installed at the patient's head at a distance of at least 15 cm from the operative table.

After docking, the robotic ports were slightly suspended to increase the intra-abdominal space, mitigate possible conflicts between arms, and reduce the median CO2 pressure to 8–10 mm Hg. An additional 12-mm tableside surgeon port was placed in a lower quadrant between the umbilical and the left port. This trocar was primarily used for the ultrasonic scalpel (Harmonic ACE+®; Johnson & Johnson Medical, Ethicon, Somerville, NJ, USA or Thunderbeat®; Olympus Corporation, Tokyo, Japan), scissors, clip applicators, suction, and stapling devices. The 30° optical scope and robotic instruments, such as graspers, and energy-based tools (e.g., monopolar and bipolar devices), were routinely used. A suprapubic Pfannenstiel incision was performed to extract the specimen, previously loaded in an Endobag. Two surgical drains were placed, as previously described in the open approach [1]. The management of the surgical drains followed the institutional policy of selective placement and early removal [11, 12].

Pancreatic-Enteric Technique

Case 1: Modified End-to-Side Blumgart Pancreaticojejunostomy with Internal (a) or External (b) Pancreatic Duct Stent

After R-PD, the pancreatic remnant was mobilized 1–2 cm from the splenic vessels, and the first jejunal loop was brought under the mesenteric root to the patient's right side. A modified end-to-side Blumgart pancreatojejunostomy was performed with non-resorbable double-armed sutures (Fig. 1, the complete description is reported in online suppl. Fig. 1 and Video1; for all online suppl. material, see www.karger.com/doi/10.1159/000528646). Since the thread length (3/0 Ti-Cron™, Medtronic) is overlong for the robotic approach, the thread was cut 10 cm from each needle; the two segments were assembled in a shorter thread, by knotting them together. The shortened double-armed suture was run through the seromuscular layer of the posterior side of the jejunum (Fig. 1a) and back through the pancreatic parenchyma from the posterior to the anterior surface, approximately 1 cm from the cut edge. Similar trans-pancreatic sutures are placed along with the pancreatic remnant from a cranial to caudal position, straddling and carefully avoiding the pancreatic duct (Fig. 1b). A small enterotomy was created opposite the main pancreatic duct. A duct-to-mucosa anastomosis was performed with 6–8 non-absorbable monofilament (5/0 GORE-TEX®; W.L. Gore & Associates, Inc.) starting from cardinal points of each semicircumference. A transanastomotic stent (PankreaPlus polyvinyl catheter; Peter Pflugbeil Gmbh Medizinische Instrumente) was consistently placed and fixed to the main pancreatic duct and the jejunal mucosa by a resorbable suture (4/0 Vicryl Rapide®, Covidien). The internal stent technique (a) is performed by inserting a 4 cm stent into the main pancreatic duct such that half of its length remains within the duct up to the stent bulge, bridges across the anastomotic site, and empties into the jejunal lumen (Fig. 1c). In contrast, the externalized technique (b) placed a longer stent, fixed similarly within the anastomotic site. The tail is exited through the jejunal loop approximately 10 cm from the hepaticojejunostomy, before the pancreatic anastomosis fashioning, employing the Wietzel technique [13] and then externalized via a stab incision in the anterior abdominal wall. The previous double-armed trans-pancreatic sutures were used to perform the seromuscular layer of the anterior side of the jejunum (Fig. 1d) and were subsequently tied to completely cover the pancreatic stump through an invagination of the intestinal loop.

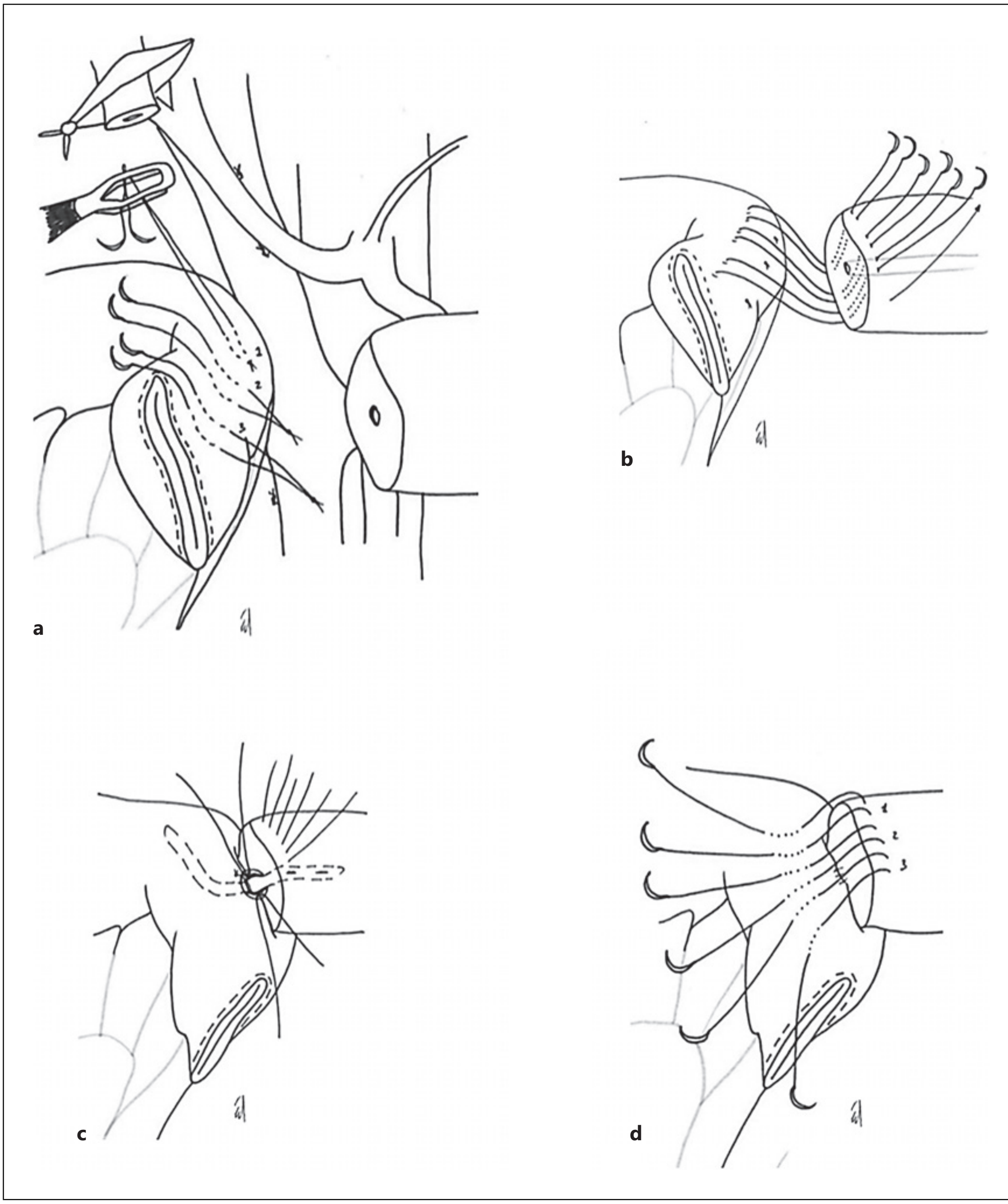

Fig. 1. Schemes of the modified end-to-side Blumgart pancreaticojejunostomy with internal pancreatic duct stent. **a** Shortened double-armed sutures running through the seromuscular layer of the posterior side of the jejunum. **b** Trans-pancreatic sutures (approximately 1 cm from the cut edge) from the posterior to the anterior surface of the pancreas, straddling the pancreatic duct. **c** Duct-to-mucosa anastomosis and internal stent placement. **d** Seromuscular layer of the anterior side of the jejunum.

Case 2: End-to-Side Cattel-Warren Duct-to-Mucosa Pancreatojejunostomy with External Pancreatic Duct Stent

After pancreaticoduodenectomy, the pancreatic stump was released 1–2 cm from splenic vessels, and the first jejunal loop was brought under the mesenteric root to the patient's right side. An end-to-side Cattel-Warren pancreatojejunostomy was performed in a two-layer fashion with interrupted non-absorbable sutures (Fig. 2, the complete description is reported in online suppl. Fig. 2 and

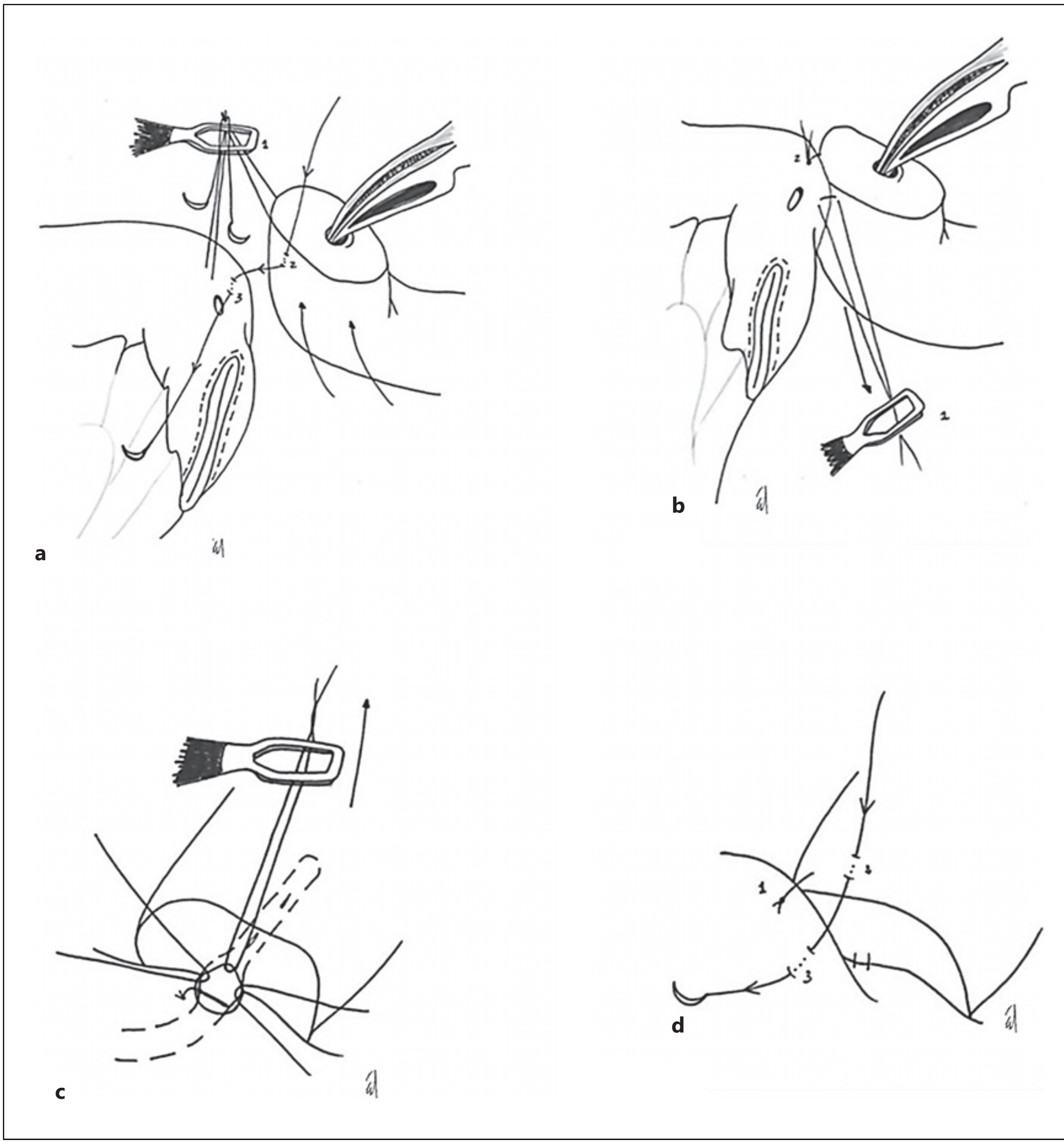

Fig. 2. Schemes of the end-to-side Cattel-Warren duct-to-mucosa pancreatojejunostomy with external pancreatic duct stent. **a** Posterior layer of the Cattel-Warren anastomosis: before the first stitch at the superior border of the anastomotic site was tied, a second one was placed in a caudal position. **b** Posterior layer of the Cattel-Warren anastomosis: stitches placed in a caudal position were gently retracted for a tension-free tying of the ones above. **c** Duct-to-mucosa anastomosis and stent placement. **d** Anterior layer of the Cattel-Warren anastomosis.

Video 2). The first single braided filament (3/0 Ti-Cron™; Medtronic) was placed at the superior border of the anastomotic site through the posterior surface of the pancreatic capsule and the seromuscular layer of the jejunal loop. Before the stitch was tied, a second one was placed in a caudal position (Fig. 2a) and gently retracted for a tension-free tying avoiding pancreatic parenchymal tearing (Fig. 2b). The posterior anastomotic layer was completed with similarly interrupted sutures tied in sequence. A duct-to-mucosa anastomosis was performed with 6–8 interrupted non-absorbable monofilament (5/0 GORE-TEX®; W.L. Gore & Associates, Inc.) for each semicircumference, depending on the main pancreatic duct diameter. A transanastomotic stent (PankreaPlus polyvinyl catheter; Peter Pflugbeil Gmbh Medizinische Instrumente) was inserted into the pancreatic duct up to the stent bulge, exited through the jejunal loop approximatively 10 cm from the hepaticojejunostomy, before the pancreatic anastomosis fashioning, using the Wietzel technique, and externalized via a stab incision in the anterior abdominal wall. The transanastomotic stent was

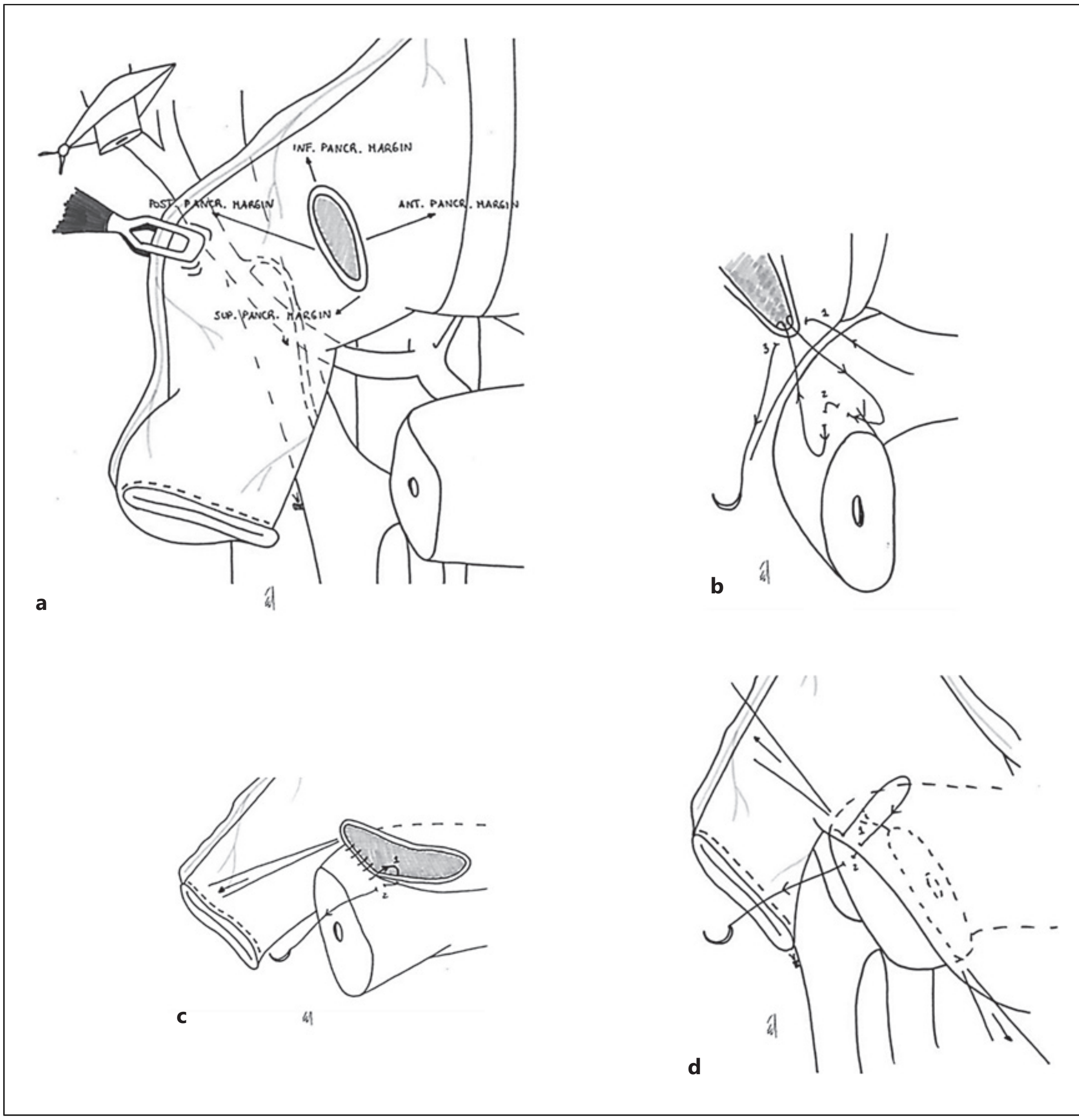

Fig. 3. Schemes of the modified end-to-side double-layer pancreogastrostomy. **a** Planning of the pancreogastrostomy with a seromuscular incision on the posterior gastric wall. **b** Anchor stitch at the pancreatic stump's cranial edge and the stomach at the medial border of the anastomotic site. **c** Running suture through the inferior seromuscular layer of the stomach and the pancreatic capsule's anterior surface - 2 cm from the pancreatic cut edge. **d** Running suture through the pancreatic capsule's posterior surface and the superior seromuscular layer of the stomach.

secured with an absorbable braided suture (4/0 Vicryl Rapide®, Covidien) to the pancreatic duct and the jejunal mucosa (Fig. 2c). Finally, the anterior layer of the anastomosis was performed with single interrupted non-absorbable braided sutures (3/0 Ti-Cron™; Medtronic) between the anterior pancreatic capsule and the seromuscular layer of the jejunal loop (Fig. 2d).

Case 3: Modified End-to-Side, Double-Layer Pancreogastrostomy

After R-PD, the pancreatic remnant was extensively mobilized 3–4 cm from splenic vessels, selectively ligating the small parenchymal branches. An end-to-side pancreaticogastrostomy was performed in a two-layer fashion with running non-absorbable sutures (Fig. 3, the complete description is reported in online suppl. Fig. 3 and Video 3). A gastrotomy in the posterior gastric wall, at the stomach's lower body, was made using the monopolar hook. Notably, the gastric opening position should be carefully evaluated when the stomach is lying naturally while considering the length of the pancreatic stump. The gastric incision should be at least 1/3 smaller than the diameter of the pancreatic stump in order to improve continence and hemostasis.

A seromuscular incision was initially performed (Fig. 3a). An anchor stitch with a non-absorbable monofilament (GORE-TEX®; W.L. Gore & Associates, Inc.) was first placed at the medial border of the anastomotic site through the stomach's seromuscular layer and the pancreatic stump's cranial edge (Fig. 3b). The pancreatogastrostomy was performed using two running non-absorbable sutures (GORE-TEX®; W.L. Gore & Associates, Inc.) or running absorbable barbed suture (V-Lok™,180, Medtronic) starting with the pancreatic capsule's anterior surface, approximately 2 cm from the cut edge and the inferior gastric incision (Fig. 3c). The gastric mucosa was subsequently opened. The pancreatic remnant was gently telescoped into the gastric cavity, and the posterior layer of the anastomosis was performed (Fig. 3d).

Results

The mean patient's age was 39 years. All patients had an ASA score <3 and a Charlson index <4. The mean operation time and estimated blood loss were 470 min and 275 mL, respectively. The average fistula risk score was 6. Following the institutional policy, surgical drains were removed on postoperative day 3, after POPF was excluded in each patient. The patients' postoperative courses were uneventful. No complications or mortality were recorded after the 90th day of operation.

Discussion

The present study demonstrated the feasibility of different pancreatic-enteric reconstructions during robot-assisted pancreatoduodenectomies. Several pancreo-enteric anastomotic techniques and management strategies have been reported in the "open-approach pancreaticoduodenectomy" literature [14, 15], but the occurrence of an anastomotic leak is still a frequent and dreadful complication after pancreatic head resections [9]. Given this drawback, risk prediction models and mitigation strategies have been implemented in clinical practice to prevent a POPF after pancreo-enteric fashioning [10, 16, 17]. As a result, during the surgical procedure, surgeons face multiple management decisions, including the type of anastomosis, use of Wirsung stents, non-absorbable versus absorbable sutures, application of biologic sealant, and drain placement [8, 13, 18–20]. These many game plans have led to a tremendous variability of practices among institutions and surgeons [21]. Consequently, even the high-level literature has failed to identify the ideal technique for a pancreatic-enteric reconstruction [9], questioning whether a "one-size-fits-all" pancreatic anastomosis is the correct strategy.

This study points the attention on different management of the pancreatic stump after R-PD. Robot-assisted pancreatic anastomosis can optionally reproduce and possibly enhance the surgical technique adopted in open pancreatic surgery, benefiting from both MI technical improvements and the pancreatic experience developed in the last decades. The dual-console robotic platform could allow better surgical field exposure thanks to the assistant's dynamic employment of the fourth robotic arm. The precise manipulation offered by the wristed instruments of robotic technology and the 3D high definition vision may advantage the anastomotic fashioning [22], potentially enhancing surgical outcomes. Different types of anastomoses can be performed during an R-PD, eventually differentiating the surgical strategy according to pancreatic gland characteristics, patients' features, and the intraoperative course. Further study investigating the effect on outcomes of personalized MI-pancreatic stump management based on risk stratification is needed, eventually with the implementation of international registries [23].

The best pancreatic-enteric reconstruction seems to balance the surgical strategy adaptability, surgeon's expertise, and technical standardization using Halsted's classic teachings, namely gentle tissues handling, an optimal blood supply, an unobstructed passage of pancreatic secretions, and a tension-free approximation [24]. These cornerstones become even more critical once a new surgical approach such as robot-assisted is implemented. In this scenario, the ability to achieve standardization of the pancreatic anastomosis technique is based not only on surgeons' skills and surgical volume but also on the MI learning curve [25–27]. Indeed, different types of pancreatic anastomosis resulted to be safe and reproducible even during MI approach [23, 28, 29].

Facing those issues, expert pancreatic surgeons have the opportunity and the responsibility to develop multiple standardized anastomotic techniques to address different and complex intraoperative scenarios. If further comparative studies between the various anastomotic techniques appear superfluous [30], the increasing use of MI approaches opens up future perspectives [8]. Multicentric studies involving high-volume centers with long experience in both pancreatic surgery and advanced MI approaches should provide evidence and future MI-pancreatic guidelines on the most suitable anastomotic techniques depending on the risk factors in the individual patient.

Conclusion

Different robotic pancreatic-enteric anastomosis techniques can be used during the reconstruction phase of a R-PD. The R-PD should be performed in high-volume centers by surgeons with extensive experience in pancreatic and advanced MI surgery, enabling different but standardized anastomotic techniques based on patients' risk factors and intraoperative findings. Future studies on MI-pancreatic anastomosis should focus on personalized approaches after adequate risk stratification.

Statement of Ethics

This study protocol was reviewed and approved by Comitato etico per la Sperimentazione Clinica delle provincie di Verona e Rovigo, approval number 1101CESC. Written informed consent was obtained from participants for publication of the details of their medical cases and any accompanying images and their participation.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Funding Sources

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Author Contributions

Matteo De Pastena, Elisa Bannone, Elena Andreotti, Chiara Filippini, Marco Ramera, Alessandro Esposito, and Roberto Salvia: study conception and design, acquisition of data, analysis and interpretation of data, drafting of manuscript, and critical revision.

Data Availability Statement

All data generated or analyzed during this study are included in this article and its supplementary material. Further inquiries can be directed to the corresponding author.

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