Curr Surg Rep (2022) 10:126–132
https://doi.org/10.1007/s40137-022-00319-8

ROBOTIC SURGERY (E BERBER, SECTION EDITOR)

Robotic Pancreatoduodenectomy: From the First Worldwide Procedure to the Actual State of the Art

Antonio Cubisino[1] · Valentina Valle[1] · Nicolas H. Dreifuss[1] · Alberto Mangano[1] · Pier Cristoforo Giulianotti[1]

Accepted: 27 May 2022 / Published online: 22 June 2022

Abstract

Purpose of Review The purpose of this review is to summarize the current experience and literature on robotic pancreatoduodenectomy and analyze its indications, surgical technique, and related peri- and postoperative outcomes.

Recent Findings Complex hepato-pancreatico-biliary (HPB) minimally invasive surgical procedures that were only attainable after a long learning curve by highly skilled laparoscopic surgeons are now robotically performed with a shorter learning curve by dedicated HPB surgeons. Image integration, fusion imaging, digital pathology, electronic tutoring, automation, telepresence, and telesurgery are the principal axis for further progress in robotic surgery.

Summary Despite growing experience in the field of pancreatic surgery, which has improved surgical outcomes, pancreatoduodenectomy remains associated with high morbidity rates. The robotic approach is a promising alternative technique and although evidence from randomized clinical trials is missing, it seems to offer many of the benefits of minimally invasive surgery without compromising the oncologic outcomes achieved in open surgery. In terms of peri- and postoperative outcomes, robotic pancreatoduodenectomy (RPD) showed reduced intraoperative blood loss, conversion rate, and length of hospital stay when compared to the open and laparoscopic approaches. Concerning the oncologic outcomes, RPD was found to be equivalent to the open and laparoscopic approaches. Still, a higher lymph-node harvest, lower resection margin involvement, and higher proportion of patients receiving adjuvant therapy were reported for RPD.

Keywords Robotic surgery · Robotic-assisted pancreatoduodenectomy · Review · Pancreatoduodenectomy · Minimally invasive surgery

Introduction

Minimally invasive pancreaticoduodenectomy (MIS-PD) has been progressively adopted over the last few decades and it is currently considered a reliable alternative to the open approach [1]. Several reports highlighted the improved peri- and postoperative outcomes obtained with the MIS approach. Among them, a high consensus level was obtained concerning the shorter length of hospital stay (LOS), reduced wound infection rate and overall morbidity rate, and improved cosmesis [2, 3]. Moreover, from an oncological standpoint, the MIS approach has been proved safe with equivalent short- and long-term outcomes when compared to the gold standard open technique [4–6]. The growing experience in the pancreatic surgery field has improved surgical outcomes. However, PD remains one of the most technically challenging operations and it's still associated with high morbidity rates.

Prior to the introduction of the robotic platform, Gagner and Pomp described the first laparoscopic PD [7]. This less invasive attempts to improve surgical outcomes did not achieve widespread adoption due to its level of technical sophistication and significant learning curve. After the Food and Drug Administration (FDA) approval of the da

This article is part of the Topical Collection on *Robotic Surgery*.

✉ Antonio Cubisino
antoniocubisino@gmail.com

[1] Division of General, Minimally Invasive and Robotic Surgery, University of Illinois at Chicago, 840 S Wood Street, Suite 435 E, Clinical Sciences Building, Chicago, IL 60612, USA

Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA, USA) in 2000, Giulianotti et al. performed the first robotic Whipple in 2001. This procedure was reported among a series of other 207 robotic operations, including 13 pancreatic procedures (8 PDs) [8]. In this large series, the first 6 patients underwent a hybrid technique with the dissection phase carried out laparoscopically and the reconstructive one robotically. In the last 2 cases, a full robotic technique was adopted. The robotic platform has improved many of the laparoscopic technical limitations, transforming complex and challenging open procedures into safe and feasible MIS operations. To analyze the key differences in outcomes after PD among the available different approaches, few randomized control trials (RCTs) and several retrospective propensity score-matched (PSM) studies compared open, laparoscopic, and robotic procedures.

This study aims to summarize the current experience and literature on RPD and analyze its indications, surgical technique, and related peri- and postoperative outcomes.

Indications and Relative Contraindications to the Robotic Approach

There are no absolute contraindications for the RPD. Even in the event of vascular involvement, the complex dissection and reconstructive phases were proved feasible in the hands of expert surgeons [9–12]. However, an accurate evaluation of anatomopathological characteristics such as the body mass index (BMI), anatomical location of the lesion, and its relation with major vascular structures are paramount during the first phase of the learning curve. Although the completion of the learning curve may allow to progressively expand the indications for the MIS approach, the boundaries of what is feasible should always be carefully evaluated to avoid major complications. Regardless of the surgical approach, the goal is to offer the best and safest treatment available without compromising the oncologic principles.

Surgical Procedure

One of the hurdles to the wider adoption of the MIS-PD is the lack of surgical standardization. This factor has limited the reproducibility and the acquisition of the technique by other surgeons. To facilitate the reproducibility and a widespread adoption of the robotic approach, we previously described a standardized step-by-step RPD technique [13, 14]. Standardization of surgical procedures is the key to shorten the learning curve and potentially improve the operative outcomes. The standardized 17 steps for RPD at the University of Illinois at Chicago (UIC) are summarized in Table 1 [13].

Perioperative Characteristics

Concerning operative time (OT), several retrospective studies compared the robotic approach with the classic open technique [15–23] .Baimas-George et al., with a PSM single-institution study, showed a similar OT between open-PD (OPD) and RPD (RPD: 392 vs. OPD: 350 min; $p = 0.10$). The authors suggested that the longer RPD OT reported by other studies might be related to the extra setup/docking required or a lack of experience at the beginning of the learning curve [21]. Interestingly Shi et al. reported a shorter OT with the robotic approach (RPD: 279.7 vs OPD: 298.2 min; $p = 0.02$) [20]. Similarly, a comparative analysis of open and robotic PDs performed at our institution revealed a significantly shorter operative time in the RPD group (RPD: 444 vs. OPD: 559 min; $p = 0.0001$) [24]. However, according to a recent meta-analysis of RCTs and PSM studies, the open technique remains the faster approach to carry out a PD [25••] In the same meta-analysis, with higher homogeneity among the included studies, estimated blood loss for RPD was significantly lower than both laparoscopic PD (LPD) and OPD

Table 1 Step-by-step operative technique for RPD at the University of Illinois at Chicago (UIC) [13]

Dissection
1. Gastrocolic ligament opening
2. Right colonic flexure mobilization
3. Kocher maneuver
4. Hilum exploration
5. Right gastric artery division
6. Right gastroepiploic artery division
7. Duodenum division
8. Cholecystectomy
9. Common bile duct transection
10. Gastroduodenal artery transection
11. First jejunal loop transection
12. Pancreatic neck transection (Fig. 1)
13. Uncinate process dissection (Fig. 2)
Reconstruction
14. Pancreatojejunostomy or pancreatogastrostomy
15. Hepaticojejunostomy
16. Pylorojejunostomy or gastrojejunostomy
17. Specimen extraction and closure

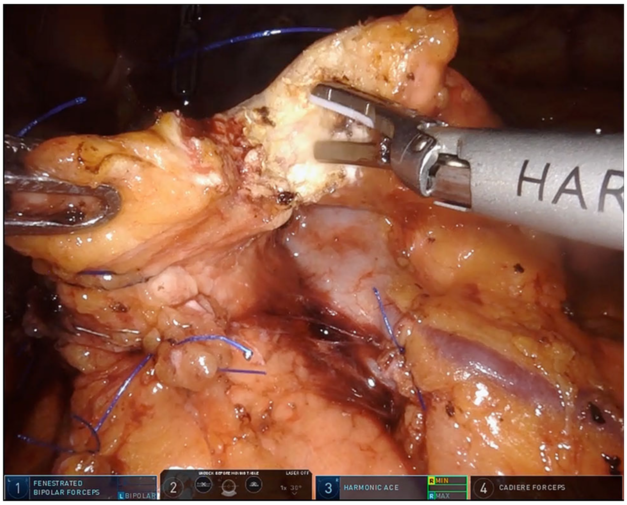

Fig. 1 Pancreatic neck transection

by a mean difference of 112.58 (95% CI 36.95–118.20) mls and 209.87 (95% CI 140.39—279.36) mls, respectively.

Moreover, when comparing LPD and RPD, 6 comparative studies highlighted the augmented rate of conversion associated with the laparoscopic approach [26–31]. Accordingly, an European multicenter retrospective cohort study of patients undergoing MIS-PD found that the laparoscopic approach was a risk factor for conversion [32•].

Postoperative Characteristics

Postoperative pancreatic fistula is one of the most common and serious complications of PDs. Following the International Study Group of Pancreatic Fistula (ISGPF) definition, it is classified as biochemical leak (previously known as grade A) or clinically relevant POPF (Cr-POPF: grade B and C) [33]. A PSM study by Cai et al. analyzed the rate of Cr-POPF in 865 patients undergoing OPD (405 cases, 46.8%) and RPD (460 cases, 53.2%). Despite the overall POPF rate being comparable between groups, the robotic approach had a lower rate of Cr-POPF (6.7% vs 15.8%, $p < 0.001$) [34•]. Other recent studies reported similar results when comparing OPD and RPD [35–37]. The reduced incidence of Cr-POPF might justify the lower reoperation rate and shorter LOS associated with the robotic approach [19, 22, 35, 36, 38]. In addition, MIS-PD is associated with a reduced wound infection rate when compared with OPD [25••, 35].

Another described advantage of the robotic approach when compared with OPD is the lower need for transfusions [18, 19, 25••, 29, 34, 38–42]. This result is related to the lower intraoperative blood loss achieved with the MIS approach.

Delayed gastric emptying, biliary anastomotic leak, postoperative bleeding, and mortality rates seem to be independent outcomes not related to the adopted surgical approach [20, 27, 29, 36, 43].

A retrospective comparison of RPD and LPD conducted by Liu et al. found a shorter LOS (RPD: 17 vs LPD: 24 days, $p = 0.01$) in the robotic group. This finding was probably related to the shorter operative time and reduced blood loss in the RPD group [26]. However, other PSM studies and RCTs showed a reduced LOS with the MIS approach but no significant differences between RPD and LPD [25••].

Oncologic Outcomes

Two PSM studies that compared OPD and RPD found an equivalent R0 resection rate but a higher number of retrieved lymph nodes with the robotic approach [19, 21]. Similar but not statistically significant results were obtained by other analyses that compared RPD and LPD [26, 43]. This supports the improved technical capabilities

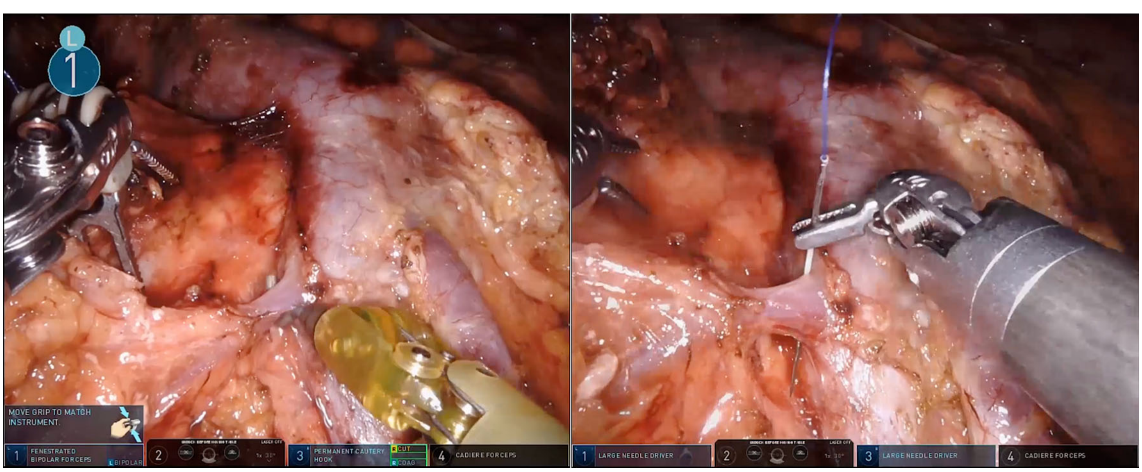

Fig. 2 Uncinate process dissection

of the robotic system in performing complex and meticulous dissections [26, 28]. A PSM analysis comparing the oncologic outcomes of RPD vs. OPD for pancreatic ductal adenocarcinoma showed comparable disease-free survival and overall survival between the two approaches [6]. A recent meta-analysis that included over 12,579 patients found that RPD provides better histopathological outcomes with significantly lower positive resection margins and a higher number of harvested lymph nodes when compared to OPD [44••].

Recent evidence highlighted the importance of neoadjuvant therapy in patients with borderline resectable pancreatic cancer [45]. However, for this specific kind of lesion, few reports investigated the role of the robotic approach. A recent retrospective analysis of the American National Cancer Database (NCDB) compared robotic and open PDs for pancreatic adenocarcinoma following neoadjuvant chemotherapy. The authors reported no differences in 90-day mortality, 30-day readmission, positive resection margin rates, and 5-year overall survival. Interestingly, the robotic approach was associated with a shorter LOS, a higher proportion of adequate lymphadenectomy, and a higher number of patients receiving adjuvant therapy [46•].

Discussion

PD is one of the most complex surgical procedures and independently from the surgical approach it is still correlated with a mortality of 1.3–6.5% [47–49]. The technical complexity and a steep learning curve required to master the LPD undoubtedly limited its broad acceptance and adoption. The introduction of robotic technology allowed surgeons to perform technically demanding procedures and overcome the intrinsic limitations of laparoscopy. With the progressive completion of the learning curve, technical refinements, and encouraging initial results, the adoption of robotic technology gained undoubtedly more acceptance [8, 50].

According to a retrospective study on the NCDB, in a study period of 7 years (2010–2016), the number of robotic cases performed increased from 2 to 7% for RPD and from 4 to 16% for robotic distal pancreatectomy ($p < 0.05$) [51]. Authors showed that surgical outcomes were not compromised in the transition to robotic surgery. Moreover, with the completion of the learning curve, there was an increased number of retrieved lymph nodes (from 18 to 21, $p = 0.035$) and a decrease in the postoperative mortality (from 6.7 to 1.8%, $p = 0.013$).

Recent international guidelines for minimally invasive pancreas resections highlighted the lack of data concerning a possible superiority of MIS-PD over the open technique [52••]. Interestingly, some PSM studies showed an equivalent R0 resection rate with the robotic and open technique but a significantly higher number of retrieved lymph nodes with the robotic approach [19, 21, 24, 53]. These results confirm a higher frequency of adequate lymphadenectomy (> 12) in RPDs compared to open procedures and support the feasibility of the robotic approach also for pancreatic malignancies. The reduction of surgical complications is considered one of the most important criteria to evaluate the superiority of a specific surgical approach. Although the surgical resection represents the main treatment for pancreatic tumors, an associated neoadjuvant or adjuvant therapy plays an important role in the management algorithm of pancreatic malignancies. In a recent retrospective study on the NCDB, Nassour et al. showed that the RPD was associated with a higher number of patients being able to receive adjuvant therapy [46•].

The Da Vinci robotic system has overcome many of the laparoscopic technical limitations, providing a magnified 3D high-definition image with depth perception, wider degree of movement with endo-wristed robotic instruments, better ergonomics, and eliminating physiological challenges such as hand tremors and computer filtration of the surgeon's movements. Accordingly, many HPB-MIS procedures that were only attainable after a long learning curve by highly skilled laparoscopic surgeons can now be performed with a shorter learning curve by dedicated HPB surgeons. This condition, applied to pancreatic complex procedures, has created a renewed interest in MIS pancreatic surgery [54]. Thanks to these advantages, an increasing number of HPB centers are developing solid MIS robotic programs with more standardized techniques that will facilitate the diffusion of the RPD and shorten its learning curve. In addition to all the mentioned technical advantages, we have to consider the development prospects of the robotic platform linked to the growing role of artificial intelligence. The robot is in fact an informatic station. Image integration, fusion imaging, digital pathology, electronic tutoring, automation, telepresence, and telesurgery are all possible applications. The growing role of robotics in surgery is part of a necessary direction of development of humankind.

Conclusions

RPD has proven to be a feasible and safe treatment with significantly reduced intraoperative blood loss, conversion rate, and LOS when compared to the open and laparoscopic approach. Concerning oncologic outcomes, RPD was found to be equivalent to open and laparoscopic procedures with the advantage of a higher number of retrieved lymph nodes, lower resection margins involvement, and a higher number of patients receiving adjuvant therapy. Well-conducted RCTs are still required to better validate the precise role of RPD. The potential and unlimited development of robotic surgery is a natural and unstoppable process that will increasingly enrich our standard of care.

Funding The authors received no specific funding for this work.

Declarations

Conflict of interest Pier Cristoforo Giulianotti has a consultant agreement with Covidien/Medtronic and Ethicon Endosurgery, and he also has an institutional agreement (University of Illinois at Chicago) for training with Intuitive. All other authors have no conflict of interest.

Research Involving Human and Animal Rights This article does not contain any studies with human or animal subjects performed by any of the authors.

Informed Consent Not applicable.

References

Papers of particular interest, published recently, have been highlighted as:

- • Of importance
- •• Of major importance

1. Tempero MA, Malafa MP, Al-Hawary M, et al. Pancreatic adenocarcinoma, version 2.2021, NCCN Clinical Practice Guidelines in Oncology. *J Natl Compr Cancer Netw*. 2021;19(4):439–457. https://doi.org/10.6004/jnccn.2021.0017
2. Zhao Z, Yin Z, Hang Z, Ji G, Feng Q, Zhao Q. A systemic review and an updated meta-analysis: minimally invasive vs open pancreaticoduodenectomy. Sci Rep. 2017;7(1):2220. https://doi.org/10.1038/s41598-017-02488-4.
3. Peng L, Lin S, Li Y, Xiao W. Systematic review and meta-analysis of robotic versus open pancreaticoduodenectomy. Surg Endosc. 2017;31(8):3085–97. https://doi.org/10.1007/s00464-016-5371-2.
4. Valle V, Fernandes E, Mangano A, et al. Robotic Whipple for pancreatic ductal and ampullary adenocarcinoma: 10 years experience of a US single-center. Int J Med Robot. 2020;16(5):1–7. https://doi.org/10.1002/rcs.2135.
5. van Hilst J, Korrel M, de Rooij T, et al. Oncologic outcomes of minimally invasive versus open distal pancreatectomy for pancreatic ductal adenocarcinoma: a systematic review and meta-analysis. Eur J Surg Oncol. 2019;45(5):719–27. https://doi.org/10.1016/j.ejso.2018.12.003.
6. Weng Y, Jiang Y, Fu N, et al. Oncological outcomes of robotic-assisted versus open pancreatoduodenectomy for pancreatic ductal adenocarcinoma: a propensity score-matched analysis. Surg Endosc. 2021;35(7):3437–48. https://doi.org/10.1007/s00464-020-07791-2.
7. Gagner M, Pomp A. Laparoscopic pylorus-preserving pancreatoduodenectomy. Surg Endosc. 1994;8(5):408–10. https://doi.org/10.1007/BF00642443.
8. Giulianotti PC. Robotics in general surgery: personal experience in a large community hospital. Arch Surg. 2003;138(7):777. https://doi.org/10.1001/archsurg.138.7.777.
9. Giulianotti PC, Addeo P, Buchs NC, Ayloo SM, Bianco FM. Robotic extended pancreatectomy with vascular resection for locally advanced pancreatic tumors. Pancreas. 2011;40(8):1264–70. https://doi.org/10.1097/MPA.0b013e318220e3a4.
10. Kauffmann EF, Napoli N, Menonna F, et al. Robotic pancreatoduodenectomy with vascular resection. Langenbecks Arch Surg. 2016;401(8):1111–22. https://doi.org/10.1007/s00423-016-1499-8.
11. Beane JD, Zenati M, Hamad A, Hogg ME, Zeh HJ, Zureikat AH. Robotic pancreatoduodenectomy with vascular resection: outcomes and learning curve. Surgery. 2019;166(1):8–14. https://doi.org/10.1016/j.surg.2019.01.037.
12. Allan BJ, Novak SM, Hogg ME, Zeh HJ. Robotic vascular resections during Whipple procedure. J Vis Surg. 2018;4:13–13. https://doi.org/10.21037/jovs.2017.12.15.
13. Giulianotti PC, Mangano A, Bustos RE, et al. Operative technique in robotic pancreaticoduodenectomy (RPD) at University of Illinois at Chicago (UIC): 17 steps standardized technique: lessons learned since the first worldwide RPD performed in the year 2001. Surg Endosc. 2018;32(10):4329–36. https://doi.org/10.1007/s00464-018-6228-7.
14. Giulianotti PC, Mangano A, Bustos RE, et al. Educational step-by-step surgical video about operative technique in robotic pancreaticoduodenectomy (RPD) at University of Illinois at Chicago (UIC): 17 steps standardized technique—lessons learned since the first worldwide RPD performed in the year 2001. Surg Endosc. 2020;34(6):2758–62. https://doi.org/10.1007/s00464-020-07383-0.
15. Wang SE, Shyr BU, Chen SC, Shyr YM. Comparison between robotic and open pancreaticoduodenectomy with modified Blumgart pancreaticojejunostomy: a propensity score–matched study. Surgery. 2018;164(6):1162–7. https://doi.org/10.1016/j.surg.2018.06.031.
16. Ielpo B, Caruso R, Duran H, et al. Robotic versus standard open pancreatectomy: a propensity score-matched analysis comparison. Updates Surg. 2019;71(1):137–44. https://doi.org/10.1007/s13304-018-0529-1.
17. Bencini L, Tofani F, Paolini C, et al. Single-centre comparison of robotic and open pancreatoduodenectomy: a propensity score-matched study. Surg Endosc. 2020;34(12):5402–12. https://doi.org/10.1007/s00464-019-07335-3.
18. Kauffmann EF, Napoli N, Menonna F, et al. A propensity score-matched analysis of robotic versus open pancreatoduodenectomy for pancreatic cancer based on margin status. Surg Endosc. 2019;33(1):234–42. https://doi.org/10.1007/s00464-018-6301-2.
19. Jin JB, Qin K, Yang Y, et al. Robotic pancreatectomy for solid pseudopapillary tumors in the pancreatic head: a propensity score-matched comparison and analysis from a single center. Asian J Surg. 2020;43(1):354–61. https://doi.org/10.1016/j.asjsur.2019.05.016.
20. Shi Y, Jin J, Qiu W, et al. Short-term outcomes after robot-assisted vs open pancreaticoduodenectomy after the learning curve. JAMA Surg. 2020;155(5):389. https://doi.org/10.1001/jamasurg.2020.0021.
21. Baimas-George M, Watson M, Murphy KJ, et al. Robotic pancreaticoduodenectomy may offer improved oncologic outcomes over open surgery: a propensity-matched single-institution study. Surg Endosc. 2020;34(8):3644–9. https://doi.org/10.1007/s00464-020-07564-x.
22. Kim HS, Han Y, Kang JS, et al. Comparison of surgical outcomes between open and robot-assisted minimally invasive pancreaticoduodenectomy. J Hepatobiliary Pancreat Sci. 2018;25(2):142–9. https://doi.org/10.1002/jhbp.522.

23. van Oosten AF, Ding D, Habib JR, et al. Perioperative outcomes of robotic pancreaticoduodenectomy: a propensity-matched analysis to open and laparoscopic pancreaticoduodenectomy. J Gastrointest Surg. 2021;25(7):1795–804. https://doi.org/10.1007/s11605-020-04869-z.
24. Buchs NC, Addeo P, Bianco FM, Ayloo S, Benedetti E, Giulianotti PC. Robotic versus open pancreaticoduodenectomy: a comparative study at a single institution. World J Surg. 2011;35(12):2739–46. https://doi.org/10.1007/s00268-011-1276-3.
25. •• Kabir T, Tan HL, Syn NL, Wu EJ, Kam JH, Goh BKP. Outcomes of laparoscopic, robotic, and open pancreatoduodenectomy: a network meta-analysis of randomized controlled trials and propensity-score matched studies. Surgery. 2022;171(2): 476–489. https://doi.org/10.1016/j.surg.2021.07.020. *This is a recent meta-analysis of randomized controlled trials and propensity-score matched studies that compares outcomes of minimally invasive and open pancreatoduodenectomy.*
26. Liu R, Zhang T, Zhao ZM, et al. The surgical outcomes of robot-assisted laparoscopic pancreaticoduodenectomy versus laparoscopic pancreaticoduodenectomy for periampullary neoplasms: a comparative study of a single center. Surg Endosc. 2017;31(6):2380–6. https://doi.org/10.1007/s00464-016-5238-6.
27. Nassour I, Wang SC, Porembka MR, et al. Robotic versus laparoscopic pancreaticoduodenectomy: a NSQIP Analysis. J Gastrointest Surg. 2017;21(11):1784–92. https://doi.org/10.1007/s11605-017-3543-6.
28. Nassour I, Choti MA, Porembka MR, Yopp AC, Wang SC, Polanco PM. Robotic-assisted versus laparoscopic pancreaticoduodenectomy: oncological outcomes. Surg Endosc. 2018;32(6):2907–13. https://doi.org/10.1007/s00464-017-6002-2.
29. Zimmerman AM, Roye DG, Charpentier KP. A comparison of outcomes between open, laparoscopic and robotic pancreaticoduodenectomy. HPB. 2018;20(4):364–9. https://doi.org/10.1016/j.hpb.2017.10.008.
30. Xourafas D, Pawlik TM, Cloyd JM. Independent predictors of increased operative time and hospital length of stay are consistent across different surgical approaches to pancreatoduodenectomy. J Gastrointest Surg. 2018;22(11):1911–9. https://doi.org/10.1007/s11605-018-3834-6.
31. Goh BKP, Low T, Kam J, Lee S, Chan C. Initial experience with laparoscopic and robotic surgery for the treatment of periampullary tumours: single institution experience with the first 30 consecutive cases. ANZ J Surg. 2019;89(4):E137–41. https://doi.org/10.1111/ans.15033.
32. • Lof S, Vissers FL, Klompmaker S, et al. Risk of conversion to open surgery during robotic and laparoscopic pancreatoduodenectomy and effect on outcomes: international propensity score-matched comparison study. British Journal of Surgery. 2021;108(1):80–87. https://doi.org/10.1093/bjs/znaa026. *This European multicentre analysis compared outcomes of converted and non-converted MIS-PD procedures.*
33. Bassi C, Marchegiani G, Dervenis C, et al. The 2016 update of the International Study Group (ISGPS) definition and grading of postoperative pancreatic fistula: 11 years after. Surgery. 2017;161(3):584–91. https://doi.org/10.1016/j.surg.2016.11.014.
34. •• Cai J, Ramanathan R, Zenati MS, et al. Robotic pancreaticoduodenectomy is associated with decreased clinically relevant pancreatic fistulas: a propensity-matched analysis. J Gastrointest Surg. 2020;24(5):1111–8. https://doi.org/10.1007/s11605-019-04274-1. *Thispropensity-matchedanalysisevaluatedtheimpactoftheroboticapproachonCr-POPF*
35. Zhang W, Huang Z, Zhang J, Che X. Safety and efficacy of robot-assisted versus open pancreaticoduodenectomy: a meta-analysis of multiple worldwide centers. Updates Surg. 2021;73(3): 893–907. https://doi.org/10.1007/s13304-020-00912-5.
36. Vining CC, Kuchta K, Schuitevoerder D, et al. Risk factors for complications in patients undergoing pancreaticoduodenectomy: a NSQIP analysis with propensity score matching. J Surg Oncol. 2020;122(2):183–94. https://doi.org/10.1002/jso.25942.
37. McMillan MT, Zureikat AH, Hogg ME, et al. A propensity score-matched analysis of robotic vs open pancreatoduodenectomy on incidence of pancreatic fistula. JAMA Surg. 2017;152(4):327. https://doi.org/10.1001/jamasurg.2016.4755.
38. Gall TMH, Pencavel TD, Cunningham D, Nicol D, Jiao LR. Transition from open and laparoscopic to robotic pancreaticoduodenectomy in a UK tertiary referral hepatobiliary and pancreatic centre—early experience of robotic pancreaticoduodenec tomy. HPB. 2020;22(11):1637–44. https://doi.org/10.1016/j.hpb.2020.03.008.
39. Girgis MD, Zenati MS, King JC, et al. Oncologic outcomes after robotic pancreatic resections are not inferior to open surgery. Ann Surg. 2021;274(3):e262–8. https://doi.org/10.1097/SLA.0000000000003615.
40. Marino MV, Podda M, Gomez Ruiz M, Fernandez CC, Guarrasi D, Gomez FM. Robotic-assisted versus open pancreaticoduodenectomy: the results of a case-matched comparison. J Robotic Surg. 2020;14(3):493–502. https://doi.org/10.1007/s11701-019-01018-w.
41. Mejia A, Shah J, Vivian E, Acharya P. Analysis of 102 fully robotic pancreaticoduodenectomies: clinical and financial outcomes. Pancreas. 2020;49(5):668–74. https://doi.org/10.1097/MPA.0000000000001545.
42. Bao PQ, Mazirka PO, Watkins KT. Retrospective comparison of robot-assisted minimally invasive versus open pancreaticoduodenectomy for periampullary neoplasms. J Gastrointest Surg. 2014;18(4):682–9. https://doi.org/10.1007/s11605-013-2410-3.
43. Kamarajah SK, Bundred J, Marc OS, et al. Robotic versus conventional laparoscopic pancreaticoduodenectomy a systematic review and meta-analysis. Eur J Surg Oncol. 2020;46(1):6–14. https://doi.org/10.1016/j.ejso.2019.08.007.
44. •• Da Dong X, Felsenreich DM, Gogna S, et al. Robotic pancreaticoduodenectomy provides better histopathological outcomes as compared to its open counterpart: a meta-analysis. Sci Rep. 2021;11(1):3774. https://doi.org/10.1038/s41598-021-83391-x. *This meta-analysis on robotic and open PDs evaluated whether the robotic approach provides better clinical and pathologic outcomes compared to its open counterpart.*
45. van Dam JL, Janssen QP, Besselink MG, et al. Neoadjuvant therapy or upfront surgery for resectable and borderline resectable pancreatic cancer: a meta-analysis of randomised controlled trials. Eur J Cancer. 2022;160:140–9. https://doi.org/10.1016/j.ejca.2021.10.023.
46. • Nassour I, Tohme S, Hoehn R, Adam MA, Zureikat AH, Alessandro P. Safety and oncologic efficacy of robotic compared to open pancreaticoduodenectomy after neoadjuvant chemotherapy for pancreatic cancer. Surg Endosc. 2021;35(5):2248–2254. doi:https://doi.org/10.1007/s00464-020-07638-w. *This retrospective study compared the postoperative, pathological and long-term oncologic outcomes of RPD and OPD for pancreatic adenocarcinoma following neoadjuvant chemotherapy.*
47. Hasegawa H, Takahashi A, Kakeji Y, et al. Surgical outcomes of gastroenterological surgery in Japan: report of the National Clinical Database 2011–2017. Ann Gastroenterol Surg. 2019;3(4):426–50. https://doi.org/10.1002/ags3.12258.
48. Liu Z, Peneva IS, Evison F, et al. Ninety day mortality following pancreatoduodenectomy in England: has the optimum centre volume been identified? HPB. 2018;20(11):1012–20. https://doi.org/10.1016/j.hpb.2018.04.008.
49. Nassour I, Winters SB, Hoehn R, et al. Long-term oncologic outcomes of robotic and open pancreatectomy in a national

cohort of pancreatic adenocarcinoma. J Surg Oncol. 2020;122(2): 234–42. https://doi.org/10.1002/jso.25958.

50. Giulianotti PC, Sbrana F, Bianco FM, et al. Robot-assisted laparoscopic pancreatic surgery: single-surgeon experience. Surg Endosc. 2010;24(7):1646–57. https://doi.org/10.1007/s00464-009-0825-4.
51. Hoehn RS, Nassour I, Adam MA, Winters S, Paniccia A, Zureikat AH. National trends in robotic pancreas surgery. J Gastrointest Surg. 2021;25(4):983–90. https://doi.org/10.1007/s11605-020-04591-w.
52. •• Asbun HJ, Moekotte AL, Vissers FL, et al. The Miami International Evidence-based Guidelines on Minimally Invasive Pancreas Resection. Ann Surg. 2020;271(1):1–14. https://doi.org/10.1097/SLA.0000000000003590. *This is the most recent landmark consensus meeting that discussed important aspects of MIS pancreatic procedures*.
53. Nassour I, Wang SC, Christie A, et al. Minimally invasive versus open pancreaticoduodenectomy: a propensity-matched study from a national cohort of patients. Ann Surg. 2018;268(1):151–7. https://doi.org/10.1097/SLA.0000000000002259.
54. Dreifuss NH, Cubisino A, Schlottmann F, Giulianotti PC. Robotic-assisted central pancreatectomy: a minimally invasive approach for benign and low-grade lesions. *Surg Oncol*. https://doi.org/10.1016/j.suronc.2022.101736