Editorial Commentary

The state of robotic *vs.* open pancreatoduodenectomy

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Pancreatoduodenectomy (PD), also known as the Whipple procedure, is a technically demanding procedure for the removal of tumors from the pancreatic head and periampullary region (1). Despite advances in operative techniques, surgical instruments, and perioperative management, traditional open PD (OPD) is still associated with high perioperative morbidities (1). Minimally invasive pancreatic resection (MIPR), including laparoscopic PD (LPD) and robotic PD (RPD), is increasingly used worldwide, with outcomes equivalent to those of OPD (2). Considering the current trends in the transition from OPD to MIPR, with growing evidence, minimally invasive PD (MIPD) using robotic platforms will increase. Understanding the current status of robotic surgery compared to open surgery is important for the further development of robotic surgery. This study aimed to describe the state of MIPD, focusing on RPD rather than on OPD. Moreover, we discuss the implementation of the MIPR program, training system, and surgical outcomes.

The Dutch Pancreatic Cancer Group developed a nationwide training program for MIPR. The feasibility of a nationwide training program for minimally invasive (MI) distal pancreatectomy, including detailed technique descriptions, video training, and on-site proctoring, has been reported (LAELAPS) (3). In the LAELAPS group, the conversion rate (38% *vs.* 8%, P<0.001) and blood loss were lower after training, and more pancreatic adenocarcinomas were resected (10% *vs.* 22%, P=0.03).

Subsequently, the feasibility and acceptable outcomes of a multicenter structured training program for LPD were confirmed as LAELAPS-2 (4). However, safety concerns and the fact that LPD has no benefits compared to OPD were suggested by a multicenter randomized controlled trial (RCT) in the Netherlands (LEOPARD-2) (5). Although a recent meta-analysis reported non-inferior short-term surgical outcomes and oncological adequacy of LPD compared with OPD when performed by highly skilled surgeons in high-volume centers (6), LPD remains a more technically challenging and time-consuming procedure. Therefore, LPD is inappropriate for use in low-volume centers.

Robotic surgery has been developed to overcome some of the preexisting drawbacks of laparoscopic surgery, including the restricted range of instrument motion and two-dimensional view (7). Robotic pancreatic surgery has become mainstream over the past decade (2). In the Netherlands, a multicenter training program for RPD was designed at the University of Pittsburgh Medical Center (UPMC), including an online video bank, robotic simulation exercises, biotissue drills, and on-site

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proctoring (LAELAPS-3) (8). As the feasibility and safety of the implementation of RPD, including an initial 635 cases, were shown (9), the nationwide annual use of RPD increased from 0% to 23%. In contrast, the use of LPD decreased from 15% to 0% between 2016 and 2021 in the Netherlands.

The Dutch Pancreatic Cancer Group conducted a nationwide retrospective database analysis of 701 RPDs and 4,447 OPDs between 2014 and 2021 (10). In the study, the primary endpoints were major complications (Clavien-Dindo classification ≥3) and in-hospital/30-day mortality. After propensity-score matching (698 RPDs *vs.* 698 OPDs), there were no significant differences in major complications (40.3% *vs.* 36.2%, P=0.186), in-hospital/30-day mortality (4.0% *vs.* 3.1%, P=0.326), and postoperative pancreatic fistula (POPF) grade B/C (24.9% *vs.* 23.5%, P=0.578); however, RPD had significantly fewer wound infections (7.4% *vs.* 12.2%, P=0.008), and a shorter hospital stay (11 *vs.* 12 days, P<0.001). Sensitivity analyses demonstrated a lower in-hospital/30-day mortality rate (2.9% *vs.* 7.3%, P=0.009) and a lower conversion rate (6.3% *vs.* 11.2%, P=0.032) in centers performing greater than 20 RPDs annually than in centers performing less than 20 RPDs annually. These findings suggest that RPD can be safely implemented nationwide without compromising surgical outcomes, including significant morbidity and mortality. Regarding oncological outcomes, the residual tumor margins were comparable between the RPD and OPD groups (R0 margin: 60.1% *vs.* 54.6%, after propensity-score matching, P=0.11). The mean ± standard deviation (SD) number of resected lymph nodes was significantly higher in the OPD group than in the non-OPD group (14±5 *vs.* 15±7, P=0.008). Data regarding the use of adjuvant chemotherapy and overall survival should be provided in future studies.

Since the International Miami Guidelines on MIPR were published in 2019, new developments and key publications have been reported, such as the Brescia Internationally Validated European Guidelines on Minimally Invasive Pancreatic Surgery (EGUMIPS) (11). In the updated guidelines, new evidence has emerged on various topics such as the role of MIPR in cancer, learning curves, and center volumes. Regarding the role of RPD in cancer, recommendations for robotic surgery for malignant diseases are weaker than those for benign and premalignant diseases. This could be because robotic surgery for malignant diseases is more challenging because of the extent of the disease and the possibility of invasion into the surrounding tissues (12). Better outcomes have been reported in centers that perform at least 20 RPD procedures (11).

Several meta-analyses investigating the outcomes of RPD and OPD have been reported. A meta-analysis by Podda included 18 non-randomized studies for quantitative synthesis with 13,639 patients allocated to the RPD (n=1,593) or OPD (n=12,046) (13). The findings showed equivalent results between the RPD and OPD groups in terms of postoperative outcomes, including mortality (3.3% *vs.* 2.8%, P=0.84), morbidity (64.4% *vs.* 68.1%, P=0.12), POPF (17.9% *vs.* 15.9%, P=0.81), delayed gastric emptying (16.8% *vs.* 16.1%, P=0.98), and bile leak (5.1% *vs.* 3.5%, P=0.35). Moreover, equivalent outcomes regarding retrieved lymph nodes (19.1±9.9 *vs.* 17.3±9.9, P=0.22) and positive margin status (13.3% *vs.* 16.1%, P=0.32) were demonstrated. One of the main concerns after PD is the intraoperative risk stratification of POPF and the choice of the most appropriate mitigation strategy (14). Several risk-score models for predicting POPF have been developed, including soft pancreatic texture and a small main pancreatic duct. Although a similar incidence of POPF between RPD and OPD has been reported, further investigations should be performed to examine the effects of robotic surgery on POPF. Another meta-analysis by Mantzavinou included four studies with 617 RPDs and 4,473 OPDs to investigate the safety and efficacy of RPD and OPD using the therapeutic index (TI) (15). The results of variance ratio tests demonstrated higher TI for RPD compared to OPD (1,807 *vs.* 1,723, P=0.86), significantly smaller 30-day mortality rates (2.5 *vs.* 19.0, P<0.001), significantly lower R0 resection rates (130.5 *vs.* 939.3, P<0.05) and no significant difference in the yield of lymph node retrieval (35.6 *vs.* 38.3, P=0.81). However, data on the long-term oncological outcomes are still lacking. Therefore, more prospective randomized studies are required to support the equivalency between RPD and OPD.

Because RPD requires a long learning curve owing to its complexity, understanding the current evidence of the learning curve of RPD is critical. A recent review, including nine studies on RPD, has reported that the number of cases required to surmount the learning curve for RPD is 36.7 (95% confidence interval: 32.9–41.0) (16). There was no significant difference between the learning curves for RPD and LPD under the limitations of the retrospective nature and heterogeneity of the published studies; however, this may be due to prior experience of laparoscopic surgery and the ergonomic advantages of robotic surgery (17). Moreover, economic evaluations should determine how cost-effective MIPR is compared with open surgery. A

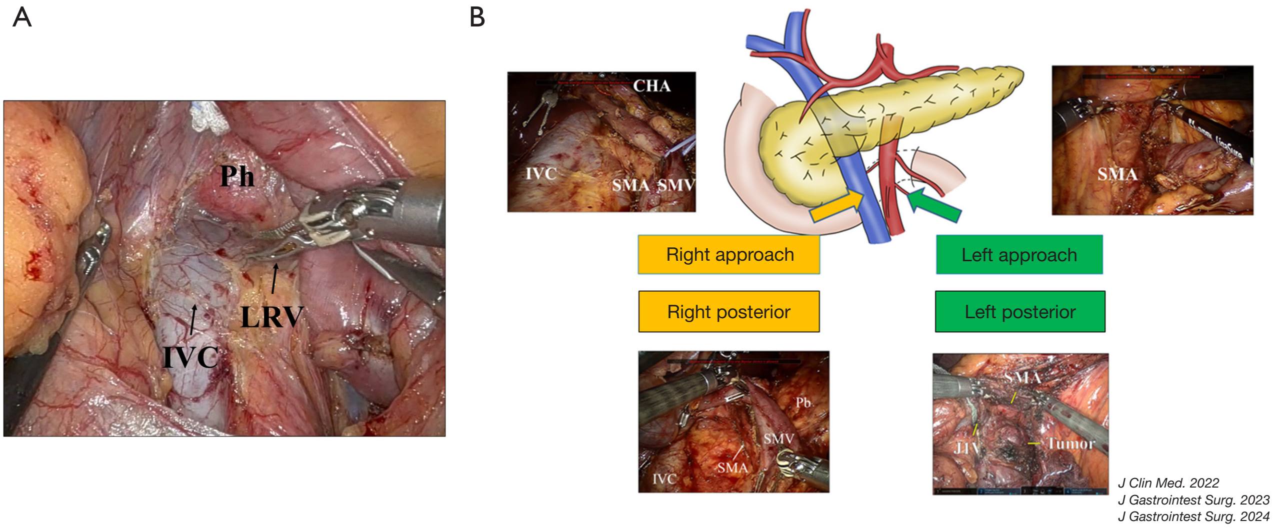

Figure 1 Innovative surgical techniques in RPD. (A) The mesenteric Kocher maneuver. (B) Surgical approaches to the superior mesenteric artery. Ph, pancreatic head; LRV, left renal vein; IVC, inferior vena cava; CHA, common hepatic artery; SMA, superior mesenteric artery; SMV, superior mesenteric vein; Pb, pancreatic body; J1V, first jejunal vein; RPD, robotic pancreatoduodenectomy.

structured training program for robotic surgery, such as LAELAPS-3 (8), and a proctoring system, may be helpful in shortening the initial learning curve. Additionally, surgical videos are useful adjuncts for trainees (18). A meta-analysis by Lee *et al.* suggested that the cost of surgical procedures, surgical instruments, and operating room occupation were higher in MIPR (19). However, the overall index hospitalization costs were similar between the MI and open pancreatic surgery groups.

Standardized surgical techniques and strategies are essential for the safe implementation of RPD. The benefits of robotics should be considered, such as finer, more ergonomic dissection to skeletonize the porta hepatis, as well as magnified vision afforded during reconstruction. Our department has introduced the Western RPD program to Japan after completing a Dutch training program (LAELAPS-3) and learning surgical techniques (20). Subsequently, we have reported on various surgical approaches for RPD. First, we reported on the mesenteric Kocher maneuver during RPD (*Figure 1A*) (21). The mesenteric Kocher maneuver provides a unique caudal view that facilitates the dissection of the duodenum and pancreatic head at the level of the left renal vein through the mesenteric route. Second, the right approach to the superior mesenteric artery is commonly used in MIPD. However, several surgical approaches have been developed for RPD, including right, right posterior, left, and left posterior approaches (*Figure 1B*) (22-24). Surgeons should understand the advantages and disadvantages of different approaches and select the best surgical approach depending on the patient and tumor characteristics. Our protocol included uncinate artery dissection in caudal view. Reconstructions included pancreaticojejunostomy anastomosis using the modified Blumgart method (20), hepaticojejunostomy anastomosis using posterior two-layer sutures (25), and stapled gastrojejunostomy anastomosis (26). Since we have successfully introduced the RPD program thanks to LAELAPS-3, our standardized surgical technique protocol can help us understand the tips, tricks, and pitfalls of safely implementing RPD. Our initial outcomes of 50 RPDs were superior to those of 50 OPDs after propensity-score matching, and comparable to those of LAELAPS-3 and UPMC (*Table 1*) (27).

In conclusion, this study summarizes the current status of RPD, focusing on its comparison with OPD. Equivalent short-term outcomes between RPD and OPD, including perioperative and oncological outcomes, have also been reported. However, further studies are required to

Table 1 Outcomes of RPD

Variables	Okayama University Hospital (27)	Netherlands: LAELAPS-3 (9)	UPMC (28)
Number of cases	50	635	500
Operative time (min)	425±66	414±111	415±107
Blood loss (mL)	75 [20–100]	200 [100–450]	250 [150–400]
Conversion	0 (0.0)	42 (6.6)	26 (5.2)
POPF (grade B/C)	3 (6.0)	171 (26.9)	39 (7.8)
DGE (grade B/C)	4 (8.0)	149 (23.5)	74 (14.8)
Bile leak	1 (2.0)	51 (8.0)	–
Postoperative hospital stays (days)	10 [8–14]	11 [7–19]	8 [6–11]
In-hospital/30-day mortality	0 (0.0)	22 (3.5)	9 (1.8)

Data are presented as n, mean ± SD, median [IQR], or n (%). RPD, robotic pancreatoduodenectomy; UPMC, University of Pittsburgh Medical Center; POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying; SD, standard deviation; IQR, interquartile range.

determine the effect of RPD on long-term outcomes.

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Footnote

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