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Robot-assisted and laparoscopic extended left pancreatectomy: a pan-European multicenter propensity-score matched analysis

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STRUCTURED ABSTRACT

Objective: To compare postoperative outcomes after extended robot-assisted left pancreatectomy (e-RLP) and extended laparoscopic left pancreatectomy (e-LLP).

Summary background data: The implementation of RLP is increasing worldwide with expanding indications, resulting in more extended resections. However, the use of e-RLP has not been investigated before.

Methods: International study including consecutive patients after e-RLP and e-LLP for all indications in 19 European countries (2012-2022). Extended resection was defined according to the ISGPS definition. Propensity score matching (PSM) was performed in a 1:1 ratio with a caliper width of 0.1. Primary endpoint was major morbidity (Clavien-Dindo grade ≥ III complications).

Results: Overall, 514 patients were included from 72 centers (152 e-RLPs; 362 e-LLPs). Before PSM, e-RLP patients had more tail tumors (69.4% vs 50.0%, p=0.001), vascular involvement (30.3% vs 16.3%, p<0.001) and >2 additional organ resections (28.5% vs 10.7%, p<0.001), with comparable major morbidity rates (27.0% vs 27.0%, p=0.991) and a lower conversion rate (15.1% vs 23.5%, p=0.033), compared to e-LLP. After PSM, 119 e-RLP patients were matched to 119 e-LLP patients. No significant differences were observed in major morbidity (23.5% vs 26.5%, p=0.599), blood loss (200 vs 150 mL, p=0.835), conversion rate (16.0% vs 20.0%, p=0.422), 30-day/in-hospital mortality (1.7% vs 3.4%, p=0.408), and hospital stay (median 7 vs 7 days, p=0.906). E-RLP had longer operative times (median 277 vs 228 min, p<0.001).

Conclusions: This pan-European cohort study found no significant differences in the outcomes among matched patients undergoing e-RLP and e-LLP, although e-RLP was associated with a longer operative time. The robot-assisted approach is used for more extensive resections with a comparable major morbidity rate compared to laparoscopy.

INTRODUCTION

Minimally invasive left pancreatectomy (MILP) has become a viable alternative to open left-sided pancreatectomy, aiming to reduce surgical trauma. The LEOPARD and LAPOP randomized controlled trials have demonstrated favorable outcomes for MILP in terms of time to functional recovery, hospital stay, blood loss and complications as compared to the open approach.[1-4] Currently, with increasing experience, indications for MILP are being expanded. The recently published REDISCOVER guidelines have acknowledged the role of minimally invasive surgery even when treating patients with borderline resectable pancreatic cancer.[5] These extended resections may include colon, stomach, adrenal glands and other organs.[6, 7]

Cohort studies on extended left-sided pancreatectomy for both benign and malignant disease have shown that this procedure can be achieved with acceptable morbidity and mortality rates and oncological outcomes.[8-11] More recently, the feasibility of extended laparoscopic left pancreatectomy (e-LLP) has been demonstrated. Comparing 65 e-LLPs to 255 open extended left-sided pancreatectomies (e-OLP), Balduzzi et al. found a high conversion rate, but comparable complication rates and reduced hospital stay for the laparoscopic group.[12] However, no data is available on the robot-assisted approach for these extended procedures.

Robot-assisted techniques are gaining popularity in pancreatic surgery, but their use comes with higher costs and longer operation times.[13] Evaluating the use of robotics is crucial to ensure cost-effective healthcare, reserving them for situations where their added value is truly evident. While the enhanced precision and maneuverability of the robot may aid in complex resections, potential technical limitations exist when maneuvers in different abdominal

quadrants are needed. Unfortunately, existing literature lacks data on robot-assisted extended left-sided pancreatectomy (e-RLP) in general, and its comparison to laparoscopy.

Hence, the primary objective of this study is to assess postoperative outcomes after e-RLP compared to e-LLP for all indications.

METHODS

Patients and design

This multicenter retrospective cohort study included patients who underwent a minimally invasive (robot-assisted or laparoscopic) extended left pancreatectomy for any indication between January 1st 2012 and December 31st 2022. Data from a large retrospective database (2012-2018) were combined with data from the prospective European consortium on minimally invasive pancreatic surgery (E-MIPS) registry (2019-2022).[14] Patients were excluded if they underwent any surgery other than extended left pancreatectomy, received palliative treatment for another malignancy, or had a history of previous pancreatic surgery. Patients were categorized according to the surgical approach: robot-assisted and laparoscopic. Ethical approval was waived due to the observational nature of the study. All data were collected and reported anonymously.

Data collection

Baseline characteristics included sex, age, body mass index (BMI, kg/m^2), American Society of Anesthesiologists (ASA) stage, surgical history, preoperative diagnosis, tumor location, vascular- and visceral involvement, and administration of neoadjuvant chemo- and/or radiotherapy. Intraoperative outcomes included type of procedure, conversion, operative time (min), blood loss (mL), specific details about involvement of other organs (extent of involvement and type of resection performed), and modified Satava classification for intraoperative events. Postoperative outcomes included major morbidity, POPF, DGE, PPH,

length of hospital stay (days), readmission, re-interventions, and 30-day or in-hospital mortality. Pathology outcomes included histopathological diagnosis, tumor and lymph node staging, tumor size (mm), overall and tumor positive lymph node yield, radical resection rate (R0), and lymphovascular and perineural invasion. Outcomes of participating centers were collected and included center volume and surgical approach. Definitions can be found in the Supplemental Methods, Supplemental Digital Content 1, http://links.lww.com/SLA/F520.

Outcomes

The primary endpoint of this study is postoperative major morbidity (Clavien-Dindo grade ≥ III complications). Secondary endpoints are intra-operative outcomes (e.g., multivisceral resection, blood loss, operative time and conversion), other postoperative outcomes (e.g., reintervention, length of hospital stay, readmission, 30-day or in-hospital mortality and ideal outcome), and pathological outcomes (e.g., diagnosis, radical resection rate, lymph node yield and involvement, lymphovascular and perineural invasion).

Statistical analysis

Data was analyzed using R (version 4.3.1. for macOS). Data was analyzed according to the intention-to-treat principles, which means that the results of a converted procedure were analyzed in the primary group. Categorical data are presented as percentages and frequencies, and were compared using the Chi-square or Fisher's exact test as appropriate. Normally distributed continuous data are presented as means and standard deviations (SDs) and were compared using the two independent samples t-test. Non-normally distributed continuous data are presented as medians and interquartile ranges (IQRs) and were compared using the Mann-Whitney U test. Propensity score matching (PSM) was applied to minimize selection bias, using the 'nearest neighbor' method.[15, 16] Patients were divided in two groups according to the

surgical approach (robot-assisted or laparoscopic). E-RLP were matched with e-LLP in a 1:1 ratio with a caliper width of 0.1. Variables used in the PSM model were: age (continuous), BMI (continuous), ASA score (dichotomous), preoperative diagnosis (adenocarcinoma or other), tumor localization, tumor size (continuous), vascular involvement, neoadjuvant therapy, and extent of multivisceral resection (1, 2 or >2 organs). Due to missing preoperative variables, tumor size is based on pathological outcomes and the extent of multivisceral resection is based on intraoperative outcomes. Standardized mean differences (SMD) were calculated to assess the balance between the groups after PSM.[16] A SMD below 0.1 was considered to indicate the optimal balance. A p-value below 0.05 was considered statistically significant.

Sensitivity analyses

Sensitivity analyses were performed within the matched cohort. First, a sensitivity analysis was performed excluding patients with only an adrenal gland resection. According to the ISGPS definition, adrenal gland resection is defined as an extended resection. However, resection of the adrenal gland is also performed in a posterior radical antegrade modular pancreatosplenectomy (RAMPS).[17, 18] Second, a sensitivity analysis was conducted excluding patients who underwent conversion from MILP to OLP. Third, a sensitivity analysis was performed including patients operated in high-volume centers (≥ 15 annual MILPs). Fourth, a sensitivity analysis was conducted including patient operated in low-volume centers (< 15 annual MILPs).

RESULTS

In total, 5115 patients underwent a left pancreatectomy and of those, 514 underwent an extended left pancreatectomy and were included in this study: 152 patients after e-RLP and 362 patients after e-LLP. Patients were included from 72 centers in 19 European countries.

Overall, 39.3% of e-RLPs and 60.6% of e-LLPs were performed in 30 high-volume centers (annually ≥15 MILPs). E-RLPs were performed significantly later in time than e-LLPs as the median year of surgery for e-RLP was 2021 (IQR 2020-2021) and for e-LLP 2020 (IQR 2018-2021, $p < 0.001$), see Figures 1 and 2.

Baseline characteristics

In the e-RLP group, fewer patients underwent previous abdominal surgery as compared to the e-LLP group (27/122, 22.1% vs 121/326, 37.1%, $p = 0.003$). Tumor localization on imaging was different between groups, with less body (23/134, 17.2% vs 87/268, 32.5%) and body-tail junction (13/134, 9.7% vs 42/268, 15.7%), and more tail tumors (93/134, 69.4% vs 134/268, 50.0%, $p = 0.001$) in the e-RLP group than in the e-LLP group, respectively. More vascular involvement on imaging was found in the e-RLP group (46/152, 30.3% vs 59/362, 16.3%, $p < 0.001$). Remaining baseline characteristics were balanced between groups, see Table 1.
After PSM, 119 patients after e-RLP were matched to 119 patients after e-LLP. All baseline characteristics were comparable, as shown in Table 1.

Intraoperative outcomes

Before matching, conversion rates were lower for e-RLP than for e-LLP (23/152, 15.1% vs 84/357, 23.5%, $p = 0.033$). Operative time was longer in e-RLP (271 min [IQR 209-355) vs 240 min [IQR 184-320), $p = 0.004$), and intraoperative blood loss was comparable between both procedures (200 mL [IQR 100-400] vs 200 mL [IQR 100-400], $p = 0.374$). Before matching, the extent of multivisceral resections was larger in the e-RLP group, as more >2 additional organ resections (43/151, 28.5% vs 38/354, 10.7%, $p < 0.001$) and less 1 additional organ resections occurred (95/151, 62.9% vs 271/354, 76.6%, $p = 0.002$). More resections of the adrenal glands (57/152, 37.5% vs 103/360, 28.6%, $p = 0.047$) and small bowel (40/152,

26.3% vs 33/360, 9.2%, p < 0.001) were performed in e-RLP compared to e-LLP. The variable 'extent and types of multivisceral resections' was used in the PSM model and was similar between e-RLP and e-LLP after PSM. After matching, operative time remained longer in e-RLP than in e-LLP (277 min [IQR 211-390] vs 228 min [IQR 178-292], p < 0.001), and intraoperative blood loss was still comparable (200 mL [IQR 100-400] vs 150 mL [IQR 100-350], p = 0.835). There was no significant difference in conversion rate anymore (19/119, 16.0% vs 23/119, 20.0%, p = 0.422). Intraoperative outcomes of the unmatched and matched cohort are shown in Table 2.

Postoperative outcomes

Before matching, postoperative outcomes were comparable between groups, as shown in Table 3. No differences were found in major morbidity rates (41/127, 27.0% vs 97/330, 27.0%, p = 0.991), and all grade B/C complication rates were comparable between e-RLP and e-LLP. Drainage (16/134, 11.9% vs 37/243, 15.2%, p = 0.380) and surgical reinterventions (11/132, 8.3% vs 25/334, 7.5%, p = 0.757) occurred similarly between groups. No differences were found in length of hospital stay (7.0 days [IQR 5.0-12.0] vs 7.0 days [IQR 6.0-11.0], p = 0.632), readmission rate (34/151, 22.5% vs 67/352, 19.0%, p = 0.372), and 30-day or in-hospital mortality (3/152, 2.0% vs 13/362, 3.6%, p = 0.335) between e-RLP and e-LLP, respectively. The rate of patients who reached ideal outcome were comparable between groups (65/130, 50.0% vs 170/327, 52.0%, p = 0.266). After matching, major morbidity occurred similarly between e-RLP and e-LLP (28/119, 23.5% vs 31/117, 26.5%, p = 0.599). All other postoperative outcomes remained comparable between groups, as reported in Table 3.

Pathological outcomes

Pathological outcomes of the unmatched and matched cohort are shown in Table 4. The oncological outcomes are displayed for patients with pancreatic ductal adenocarcinoma (PDAC). In total, 60 patients in the e-RLP group and 144 patients in the e-LLP group had PDAC. Before matching, tumor (T) stage, lymph node (N) stage and metastasis (M) stage were comparable between groups. There was a lower lymph node (LN) yield after e-RLP compared to e-LLP (15 [9-19] vs 19 [12-27], p = 0.020), but the number of positive LNs were comparable between groups (1 [IQR 0-2] vs 1 [IQR 0-4], p = 0.254). Radical resection rates were similar between e-RLP and e-LLP (24/45, 53.3% vs 83/131, 63.4%, p = 0.312). Perineural invasion occurred significantly less in the e-RLP group (13/52, 25.0% vs 45/93, 48.4%, p = 0.010), and there was a trend for lymphovascular invasion to occur less frequently in the e-RLP group (14/52, 26.9% vs 41/93, 44.1%, p = 0.062). In the matched cohort, 48 patients in the e-RLP group (48/119, 40.3%) and 48 patients in the e-LLP group (48/119, 40.3%) had PDAC. After matching, there were no significant differences in pathological outcomes between groups.

Low- and high-volume centers

Two sensitivity analyses were performed, comparing outcomes between e-RLP and e-LLP in high- and low-volume centers separately, see Supplementary Tables S1-8, Supplemental Digital Content 1, http://links.lww.com/SLA/F520. In high-volume centers, operative time was longer in e-RLP compared to e-LLP (269 min [210-326] vs 209 min [165-276], p = 0.003), while the conversion rate was similar between e-RLP and e-LLP (6/43, 14.0% vs 13/72, 18.1%, p = 0.754). Major morbidity (14/43, 32.6% vs 22/75, 28.9%, p = 0.838) and reoperation rates (4/36, 11.1% vs 5/71, p = 0.744) were also comparable between groups. In low-volume centers, operative time was comparable in both groups (281 min [214-374] vs 242 min [197-317], p = 0.221), as was conversion (13/74, 17.6% vs 10/43, 23.3%, p = 0.613)

and major morbidity (14/74, 18.9% vs 9/43, 22.0%, p = 0.884). Reoperation occurred in 1.6% of e-RLP patients (1/74, 1.6%) and in 10.5% of e-LLP patients (4/43, 10.5%, p = 0.120).

Sensitivity analyses

The other sensitivity analyses, excluding patients with only an adrenal gland resection and excluding patients who underwent conversion from MILP to OLP are shown in Supplementary Tables S9-16, Supplemental Digital Content 1, http://links.lww.com/SLA/F520. These sensitivity analyses showed a longer operative time in e-RLP compared to e-LLP, with similar major morbidity and conversion rates.

DISCUSSION

This first international multicenter propensity-score matched study to compare robot-assisted versus laparoscopic extended left pancreatectomy for all indications showed comparable major morbidity rates, length of hospital stay, 30-day/in-hospital mortality, and ideal outcome rates between both groups before and after matching. In the non-matched e-RLP cohort, there were more tail tumors, vascular involvement and >2 organ resections compared to e-LLP, yet conversion rates were significantly lower, and the major morbidity rate was comparable between groups. After matching, major morbidity rates and conversion rates were comparable between groups, while operative time was longer in e-RLP.

The outcomes of the current study cannot be compared to other studies as it is the first to compare the outcomes of RLP and LLP for extended resections. Almost all the available literature on extended LP compared outcomes of extended resections to standard LP resections, and did not stratify for surgical approach. Two studies investigated outcomes of different surgical approaches in extended resections but focused only on the laparoscopic and open approach. Balduzzi et al. compared e-LLP to the traditional open approach for extended

left-sided pancreatectomy in patients with PDAC, and reported a major morbidity rate of 25% after e-LLP.[12] Another study compared e-LLP to standard LLP in patients with PDAC and found a major morbidity rate of 19% in e-LLP.[19] In the present study, we found major morbidity rates of 30% and 29% for e-RLP and e-LLP, respectively. These slightly higher rates are yet unexplained.

Before matching, it was evident that patients undergoing e-RLP had undergone more extensive resections, including vascular involvement and additional organ resections, compared to those undergoing e-LLP. Nevertheless, the major morbidity rate in the non-matched cohort was comparable between the two groups and the conversion rate was even lower in patients undergoing e-RLP. After adjusting for preoperative diagnosis, tumor localization, vascular involvement, and extent of resection through matching, there was no statistically significant difference in conversion rates anymore. This outcome was unexpected, considering that prior to matching, e-RLP patients exhibited fewer conversions in more extensive resections. This could perhaps be explained by the fact that there were more tail tumors in the e-RLP group before matching, which are known to be technically easier resections than pancreatic body resections.[20] However, it should be noted that a valid definition for pancreatic body and tail resections was not yet established at the time of this investigation; fortunately, one now exists and ought to be applied in further research.[20] Additionally, as experience with MILP for extended resections will grow and larger patient cohorts will become available, further research will be required to evaluate the potential differences between e-RLP and e-LLP.

A striking finding of the present study are the high conversion rates of 15% and 24% during e-RLP and e-LLP, respectively. In standard LP, conversion rates are known to be lower. A

systematic review including 36 studies reported conversion rates of 6% (36/590 patients) in non-extended RLP and 15% (117/764 patients) in non-extended LLP.[21] The higher rates in the current study could partially be attributed to the fact that multivisceral resection is known to be an independent risk factor for conversion due to the technical difficulty.[22-25] This also aligns with the findings of Balduzzi et al., who reported a conversion rate as high as 36% in e-LLP. The single-center study of Sahakyan et al. found a conversion rate of 16% in e-LLP, but did report this rate to be significantly higher than the 3% conversion rate they found in standard LP.[19] Another possible explanation could be that, even though surgeons have completed the learning curve for MILP, the learning curve for extended LP might be longer as multivisceral resections are more difficult to perform. Additionally, some centers may start a minimally invasive procedure with a low threshold for conversion in the event of unforeseen tumor involvement. Giving precedence to a safe, planned conversion rather than an emergency conversion indicates a more favorable scenario, such a strategy may not be disadvantageous. Further research should focus on the differences in emergency conversion between both approaches.

The longer operative time observed in e-RLP compared to e-LLP aligns with previous studies on robot-assisted pancreatic surgery, and likely reflects the additional time required for robot preparation and docking.[13] This is supported by our finding that operative time for e-RLP remained similar across center volumes, while operative time for e-LLP decreased with experience. Although a longer operative time may raise costs, potential benefits like improved bleeding control through enhanced dexterity and 3D visualization, and tremor filtration should be considered. In our study, conversion rates were lower in the unmatched e-RLP cohort, despite more complex cases, but after matching, conversion rates and major morbidity rates were comparable between groups, suggesting that the additional operative time may not

necessarily translate into improved short-term outcomes. A formal cost-effectiveness analysis would be necessary to determine whether the technical advantages of robotic surgery justify the increased operative duration and associated costs in extended left pancreatectomy.

Our sensitivity analyses comparing outcomes between high- and low-volume centers revealed notable findings. In high-volume centers, operative time was significantly longer for e-RLP than for e-LLP, but conversion and major morbidity rates were similar between groups. In low-volume centers, operative time, conversion rates, and major morbidity were all comparable between e-RLP and e-LLP. Interestingly, morbidity rates were slightly lower in low-volume centers, despite the expectation that high-volume centers would have better outcomes due to greater experience. The PORSCH trial similarly found no significant difference in morbidity between high- and low-volume centers, while a study from Korrel et al. reported higher morbidity rates in intermediate-volume centers compared to low-volume centers, suggesting that factors beyond volume alone, such as perioperative care and failure to rescue, may influence outcomes.[26, 27]

Until the recent past, the oncological safety of minimally invasive techniques for resection of left-sided PDAC was a topic of debate.[28] Now, the multicenter DIPLOMA randomized trial has confirmed the non-inferiority of MILP compared to OLP in patients with left-sided PDAC. However, in this study only 15% of the included patients underwent multivisceral resection. The study of Balduzzi et al., that focused solely on patients after extended resections, reported a lower LN yield in e-LLP when compared to e-OLP (14 vs 18), attributing this to patient selection. In the current study, the LN yield in e-LLP was 19 and in e-RLP 15. Since this study involved more recent procedures, the higher LN yield for e-LLP may reflect completion of the laparoscopic learning curve. Conversely, the lower LN yield in

e-RLP could be due to a less advanced learning curve. The potentially less progressed learning curve of e-RLP might explain why the LN yield in e-RLP was lower. However, it is important to note that this study did not utilize standardized pathology reporting, so inter-center variability could also explain the differences. Future research should investigate the oncological safety of robot-assisted extended resections beyond the learning curve, using standardized pathology reporting.

The outcomes of this study must be interpreted considering some limitations. First, data was collected on the types of multivisceral resections performed, including the stomach, adrenal glands, small bowel, colon, and an "other" category. We did not specify the exact procedures included in the "other" group, which may introduce variability in surgical complexity within this category. However, when performing a sensitivity analysis excluding the ‘other’ group, similar major morbidity rates were found between e-RLP and e-LLP. Additionally, no data were available regarding the technical difficulty of the surgery besides the extent of resection. It is possible that other factors occurred that could have influenced the outcomes. Second, no data were available regarding surgeon experience and the phase of the learning curve that surgeons were in, which may have had impact on the outcomes. Third, the study lacked data on the reasons for conversion, preventing us from distinguishing between planned and emergency conversions. There may be differences in the reasons for conversion between the groups, and emergency conversions could potentially be associated with worse outcomes compared to planned conversions. However, the sensitivity analyses excluding conversions yielded postoperative results similar to the complete cohort. Fourth, although both groups were balanced after matching, they might still differ in unmeasured and unmatched patient characteristics leading to residual confounding. Fifth, the international and multicenter aspect of this study comes with differences in health care systems across Europe which could have

an influence on outcomes such as hospital stay and readmission. Sixth, a standardized definition for pancreatic body and tail resections was not available at the time of this study, limiting consistency in classification; future research should apply the now-established criteria.[20] Seventh, not all European centers performing MILP participate in the E-MIPS registry, since this is not mandatory. Selection bias could emerge from certain centers choosing not to participate due to insecurity about their results. Nevertheless, patients from 72 centers from 19 countries were included in this study, which may be regarded as representative for the current practice in pancreatic surgery across Europe.

In conclusion, this international multicenter propensity-score matched study suggests that robot-assisted and laparoscopic approaches for extended left pancreatectomy yield comparable short-term outcomes. The robot-assisted approach was associated with a longer operative time, both before and after matching for the extent of resection. Despite being utilized for more extensive resections, the robot-assisted approach demonstrated comparable major morbidity rates to laparoscopy. The high conversion rates in both groups underscore the need for further investigation into minimally invasive techniques for extended procedures.

REFERENCES

1 Bjornsson B, Larsson AL, Hjalmarsson C et al. Comparison of the duration of hospital stay after laparoscopic or open distal pancreatectomy: randomized controlled trial. Br J Surg 2020.

2 de Rooij T, van Hilst J, van Santvoort H et al. Minimally Invasive Versus Open Distal Pancreatectomy (LEOPARD): A Multicenter Patient-blinded Randomized Controlled Trial. Ann Surg 2018.

3 Korrel M, Vissers FL, van Hilst J et al. Minimally invasive versus open distal pancreatectomy: an individual patient data meta-analysis of two randomized controlled trials. HPB (Oxford) 2021; 23 (3): 323-330.

4 Korrel M, Roelofs A, van Hilst J et al. Long-Term Quality of Life after Minimally Invasive vs Open Distal Pancreatectomy in the LEOPARD Randomized Trial. J Am Coll Surg 2021; 233 (6): 730-739 e739.

5 Boggi U, Kauffmann E, Napoli N et al. REDISCOVER International Guidelines on the Perioperative Care of Surgical Patients With Borderline-resectable and Locally Advanced Pancreatic Cancer. Ann Surg 2024; 280 (1): 56-65.

6 Hartwig W, Vollmer CM, Fingerhut A et al. Extended pancreatectomy in pancreatic ductal adenocarcinoma: definition and consensus of the International Study Group for Pancreatic Surgery (ISGPS). Surgery 2014; 156 (1): 1-14.

7 Lof S, Moekotte AL, Al-Sarireh B et al. Multicentre observational cohort study of implementation and outcomes of laparoscopic distal pancreatectomy. Br J Surg 2019; 106 (12): 1657-1665.

8 Irani JL, Ashley SW, Brooks DC et al. Distal pancreatectomy is not associated with increased perioperative morbidity when performed as part of a multivisceral resection. J Gastrointest Surg 2008; 12 (12): 2177-2182.

9 Kleeff J, Diener MK, Z'Graggen K et al. Distal pancreatectomy: risk factors for surgical failure in 302 consecutive cases. Ann Surg 2007; 245 (4): 573-582.

10 Panzeri F, Marchegiani G, Malleo G et al. Distal pancreatectomy associated with multivisceral resection: results from a single centre experience. Langenbecks Arch Surg 2017; 402 (3): 457-464.

11 Seeliger H, Christians S, Angele MK et al. Risk factors for surgical complications in distal pancreatectomy. Am J Surg 2010; 200 (3): 311-317.

12 Balduzzi A, van Hilst J, Korrel M et al. Laparoscopic versus open extended radical left pancreatectomy for pancreatic ductal adenocarcinoma: an international propensity-score matched study. Surg Endosc 2021; 35 (12): 6949-6959.

13 van Ramshorst TME, van Bodegraven EA, Zampedri P et al. Robot-assisted versus laparoscopic distal pancreatectomy: a systematic review and meta-analysis including patient subgroups. Surg Endosc 2023.

14 van der Heijde N, Vissers FL, Boggi U et al. Designing the European registry on minimally invasive pancreatic surgery: a pan-European survey. HPB (Oxford) 2021; 23 (4): 566-574.

15 Ho D, Imai K, King G et al. MatchIt: Nonparametric Preprocessing for Parametric Causal Inference. Journal of Statistical Software 2011; 42 (8): 1 - 28.

16 Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. Multivariate Behav Res 2011; 46 (3): 399-424.

17 Strasberg SM, Drebin JA, Linehan D. Radical antegrade modular pancreatosplenectomy. Surgery 2003; 133 (5): 521-527.

18 Strasberg SM, Linehan DC, Hawkins WG. Radical antegrade modular pancreatosplenectomy procedure for adenocarcinoma of the body and tail of the

pancreas: ability to obtain negative tangential margins. J Am Coll Surg 2007; 204 (2): 244-249.

19 Sahakyan MA, Kleive D, Kazaryan AM et al. Extended laparoscopic distal pancreatectomy for adenocarcinoma in the body and tail of the pancreas: a single-center experience. Langenbecks Arch Surg 2018; 403 (8): 941-948.

20 van Ramshorst TME, van Hilst J, Boggi U et al. Standardizing definitions and terminology of left-sided pancreatic resections through an international Delphi consensus. Br J Surg 2024; 111 (4).

21 Gavriilidis P, Roberts KJ, Sutcliffe RP. Comparison of robotic vs laparoscopic vs open distal pancreatectomy. A systematic review and network meta-analysis. HPB (Oxford) 2019; 21 (10): 1268-1276.

22 Balduzzi A, van der Heijde N, Alseidi A et al. Risk factors and outcomes of conversion in minimally invasive distal pancreatectomy: a systematic review. Langenbecks Arch Surg 2021; 406 (3): 597-605.

23 Hua Y, Javed AA, Burkhart RA et al. Preoperative risk factors for conversion and learning curve of minimally invasive distal pancreatectomy. Surgery 2017; 162 (5): 1040-1047.

24 Casadei R, Ingaldi C, Ricci C et al. Laparoscopic versus open distal pancreatectomy: a single centre propensity score matching analysis. Updates Surg 2021.

25 Giani A, van Ramshorst T, Mazzola M et al. Benchmarking of minimally invasive distal pancreatectomy with splenectomy: European multicentre study. Br J Surg 2022; 109 (11): 1124-1130.

26 Smits FJ, Henry AC, Besselink MG et al. Algorithm-based care versus usual care for the early recognition and management of complications after pancreatic resection in

the Netherlands: an open-label, nationwide, stepped-wedge cluster-randomised trial. Lancet 2022; 399 (10338): 1867-1875.

27 Korrel M, van Hilst J, Bosscha K et al. Nationwide use and Outcome of Minimally Invasive Distal Pancreatectomy in IDEAL Stage IV following a Training Program and Randomized Trial. Annals of Surgery 2024; 279 (2): 323-330.

28 van Hilst J, de Rooij T, Abu Hilal M et al. Worldwide survey on opinions and use of minimally invasive pancreatic resection. HPB (Oxford) 2017; 19 (3): 190-204.

Figure 1. Flow-chart of patient inclusion

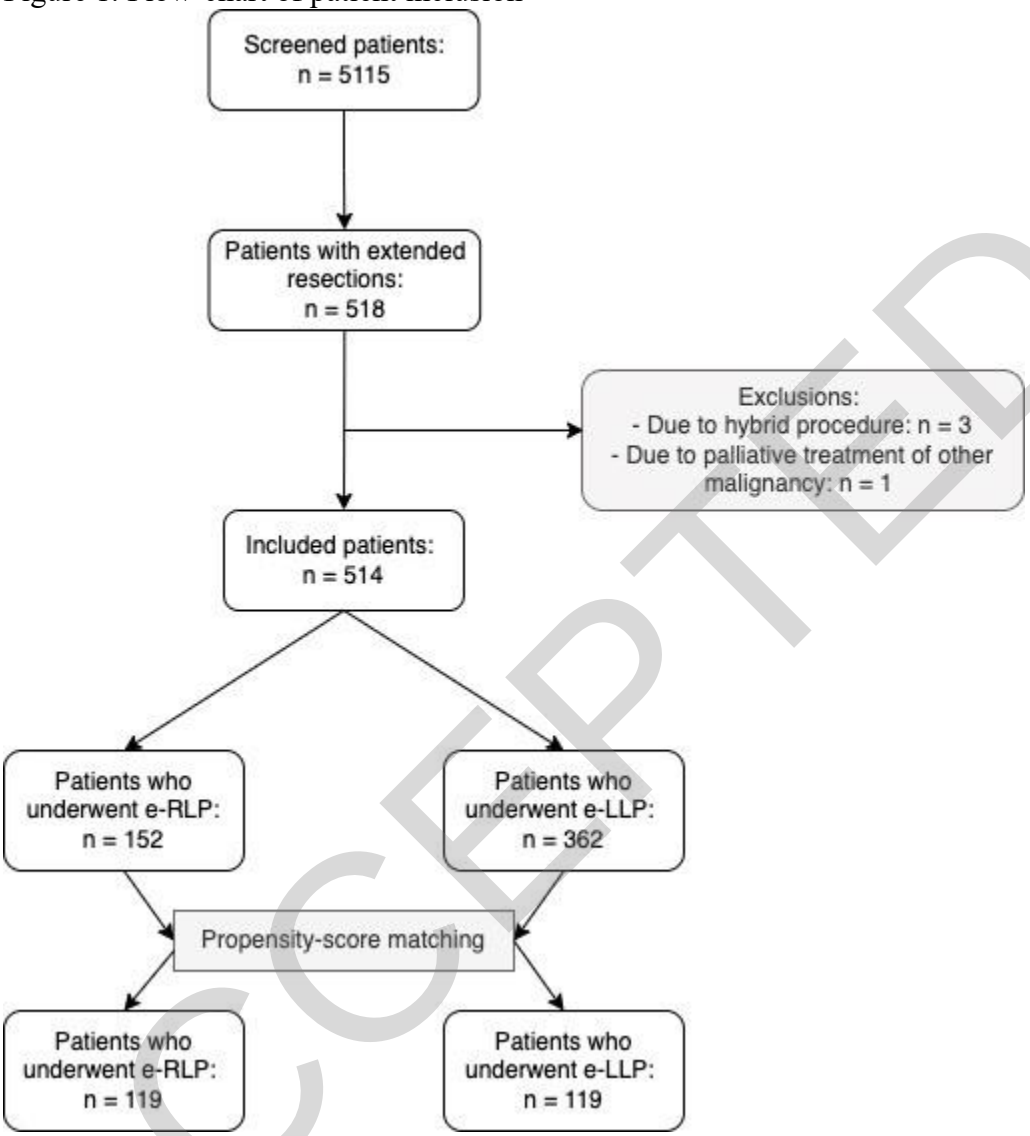
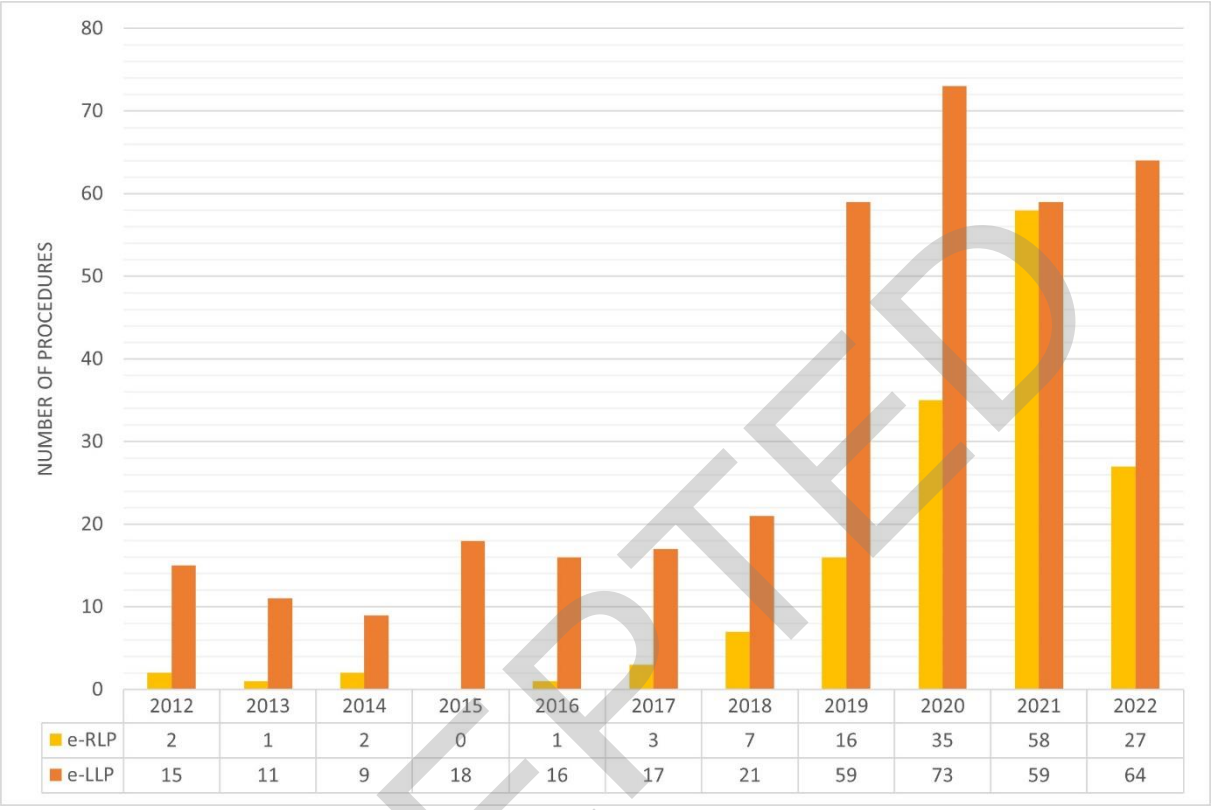


Figure 2. Annual volume of robot-assisted and laparoscopic extended left pancreatectomy



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
e-RLP	2	1	2	0	1	3	7	16	35	58	27
e-LLP	15	11	9	18	16	17	21	59	73	59	64

Table 1. Baseline characteristics in the unmatched and matched cohort

	Total cohort				**Cohort after propensity-score matching**			
	e-RLP (n = 152)	**e-LLP (n = 362)**	**p-value**	**SMD**	**e-RLP (n = 119)**	**e-LLP (n = 119)**	**p-value**	**SMD**
Age, years (median, [IQR])	66 [58-74]	66 [55-73]	0.530	0.071	66 [58-75]	65 [55-74]	0.628	0.047
Sex Male Female	73 (48.0) 79 (52.0)	162 (44.8) 200 (55.2)	0.496	0.066	58 (48.7) 61 (51.3)	57 (47.9) 62 (52.1)	0.897	0.017
BMI, kg/m^2 (median, [IQR])	25.3 [22.9-28.8]	25.6 [22.7-29.1]	0.901	0.009	25.3 [23.0-29.3]	26.1 [23.3-29.9]	0.346	0.086
ASA classification$^{\phi}$ I or II III or IV *Unknown*	95 (64.6) 52 (35.4) 5 (3.3)	200 (59.5) 136 (40.5) 26 (7.2)	0.290	0.105	75 (65.8) 39 (34.2) 5 (4.2)	65 (54.6) 46 (41.4) 8 (6.7)	0.263	0.150
Previous abdominal surgery$^{\phi}$ *Unknown*	27 (22.1) 30 (19.7)	121 (37.1) 36 (9.9)	**0.003**	0.333	20 (21.3) 25 (21.0)	28 (25.9) 11 (9.2)	0.439	0.110
#Preoperative diagnosis Adenocarcinoma (PDAC or other) Benign or premalignant *Unknown*	79 (52.3) 72 (47.7) 1 (0.7)	161 (45.4) 194 (54.6) 7 (1.9)	0.151	0.140	62 (52.1) 57 (47.9) -	60 (50.4) 59 (49.6) -	0.795	0.034
#Tumor localization on imaging$^{\phi}$ Body Body-tail junction Tail	23 (17.2) 13 (9.7) 93	87 (32.5) 42 (15.7) 134	**0.001**	0.456	23 (19.3) 13 (10.9) 80	22 (18.5) 12 (10.1) 83	0.957	0.073

Other	(69.4) 5 (3.7)	(50.0) 5 (1.9)			(67.2) 3 (2.5)	(69.7) 2 (1.7)		
Tumor size in pathology, mm (median, [IQR])	35.0 [22-50]	39.0 [25-55]	0.157	0.094	35.5 [21.3-50.0]	39.0 [20.0-51.0]	0.655	0.010
#Vascular involvement on imaging Venous involvement$^{\phi}$ *Unknown* Arterial involvement$^{\phi}$ *Unknown*	46 (30.3) 41 (31.1) 20 (13.2) 40 (30.1) 20 (13.2)	59 (16.3) 32 (13.3) 122 (33.7) 34 (14.2) 122 (33.7)	**<0.001**	0.335	30 (25.2) 26 (23.0) 6 (5.0) 26 (22.8) 5 (4.2)	29 (24.4) 25 (22.3) 7 (5.9) 24 (21.4) 7 (5.9)	0.881	0.019
Neoadjuvant treatment$^{\phi}$ *Unknown*	20 (14.1) 10 (6.6)	34 (9.7) 11 (3.0)	0.157	0.136	19 (16.0) -	16 (13.4) -	0.583	0.071
Year of surgery (median, [IQR])	2021 [2020-2021]	2020 [2018-2021]	**<0.001**	0.533	2020 [2020-2021]	2021 [2020-2021]	0.788	0.091
High volume (≥ 15 MILP/year) *Unknown*	59 (39.3) 2 (1.3)	218 (60.6) 2 (0.6)	**<0.001**	0.434	43 (36.8) 2 (1.7)	76 (63.9) -	**<0.001**	0.563

Variables used for propensity-score matching. $^{\phi}$ Percentages do not add up due to missing values.
Values are n (%) unless otherwise indicated.
Abbreviations: e-RLP: robot-assisted extended left-sided pancreatectomy; e-LLP: laparoscopic extended left-sided pancreatectomy; SMD: standardized mean difference; IQR: interquartile range; BMI, body mass index; ASA, American Society of Anesthesiologists; PDAC: pancreatic ductal adenocarcinoma; mm: millimeters; MILP: minimally invasive left-sided pancreatectomies.

Table 2. Intraoperative outcomes in the unmatched and matched cohort

	Total cohort				**Cohort after propensity-score matching**			
	e-RLP (n = 152)	**e-LLP (n = 362)**	**p-value**	**SMD**	**e-RLP (n = 119)**	**e-LLP (n = 119)**	**p-value**	**SMD**
Operative time, min (median, [IQR])	271 [209-355]	240 [184-320]	**0.004**	0.266	277 [211-354]	228 [178-292]	**<0.001**	0.460
Blood loss, mL (median, [IQR])	200 [100-400]	200 [100-400]	0.374	0.090	200 [100-400]	150 [100-350]	0.835	0.045
Conversion	23 (15.1)	84 (23.5)	**0.033**	0.214	19 (16.0)	23 (20.0)	0.422	0.105
#Extent of multivisceral resection[ϕ] 1 organ 2 organs > 2 organs *Unknown*	95 (62.9) 13 (8.6) 43 (28.5) 1 (0.7)	271 (76.6) 45 (12.7) 38 (10.7) 8 (2.2)	**0.002** 0.186 **<0.001**	0.300 0.133 0.458	79 (66.4) 12 (10.1) 28 (23.5) -	77 (64.7) 13 (10.9) 29 (24.4) -	0.785 0.833 0.879	0.035 0.027 0.020
Type of multivisceral resection [ϕ] Stomach Adrenal glands Small bowel Colon Other *Unknown*	19 (12.5) 57 (37.5) 40 (26.3) 15 (9.9) 67 (44.1) -	67 (18.6) 103 (28.6) 33 (9.2) 44 (12.2) 96 (26.7) 2 (0.6)	0.091 **0.047** **<0.001** 0.446 **<0.001**	0.169 0.190 0.461 0.075 0.370	16 (13.4) 35 (29.4) 25 (21.0) 10 (8.4) 48 (40.3) -	20 (16.8) 40 (33.6) 26 (21.8) 12 (10.1) 39 (32.8) -	0.469 0.485 0.874 0.654 0.226	0.094 0.091 0.020 0.058 0.158

Concomitant splenectomy[ϕ] *Unknown*	130 (86.1) 1 (0.7)	309 (85.8) 2 (0.6)	0.939	0.007	103 (87.3) 1 (0.8)	102 (86.4) 1 (0.8)	0.847	0.025
Intraoperative events (Satava classification)[ϕ] None Grade 1 Grade 2 Grade 3 *Unknown*	55 (72.4) 2 (2.6) 19 (25.0) - 76 (50.0)	123 (66.1) 11 (5.9) 52 (28.0) - 176 (48.6)	0.437	0.186	55 (74.3) 2 (2.7) 17 (23.0) - 45 (37.8)	55 (64.7) 6 97.1) 24 (28.2) - 34 (28.6)	0.294	0.253

[#] Variables used for propensity-score matching. [ϕ] Percentages do not add up due to missing values.
Values are n (%) unless otherwise indicated.
Abbreviations: e-RLP: robot-assisted extended left-sided pancreatectomy; e-LLP: laparoscopic extended left-sided pancreatectomy; SMD: standardized mean difference; IQR: interquartile range.

Table 3. Postoperative outcomes in the unmatched and matched cohort

	Total cohort			**Cohort after propensity-score matching**		
	e-RLP (n = 152)	**e-LLP (n = 362)**	**p-value**	**e-RLP (n = 119)**	**e-LLP (n = 119)**	**p-value**
Major morbidity *Unknown*	41 (27.0) -	97 (27.0) 3 (0.8)	0.991	28 (23.5) -	31 (26.5) 2 (1.7)	0.599
POPF grade B/C[ϕ] *Unknown*	31 (20.7) 2 (1.3)	88 (24.6) 4 (1.1)	0.342	23 (19.7) 2 (1.7)	31 (26.5) 2 (1.7)	0.215
PPH grade B/C[ϕ] *Unknown*	8 (5.3) 1 (0.7)	25 (7.0) 5 (1.4)	0.476	7 (5.9) 1 (0.8)	6 (5.1) 2 (1.7)	0.787
DGE grade B/C[ϕ] *Unknown*	1 (0.7) 2 (1.3)	2 (0.6) 7 (1.9)	0.890	1 (0.9) 2 (1.7)	1 (0.9) 3 (2.5)	0.995
Chyle leak[ϕ] *Unknown*	- 20 (13.2)	2 (0.8) 121 (33.4)	0.294	- 6 (5.0)	1 (0.9) 7 (5.9)	0.314
Drainage[ϕ] *Unknown* Radiological Endoscopic	16 (11.9) 18 (11.8) 16 (11.9) 2 (1.5)	37 (15.2) 119 (32.9) 24 (9.9) 5 (2.1)	0.380	15 (13.0) 4 (3.4) 14 (12.2) 2 (1.7)	11 (9.6) 5 (4.2) 11 (9.6) 3 (2.6)	0.418
Reoperation[ϕ] *Unknown*	11 (8.3) 20 (13.2)	25 (7.5) 28 (7.7)	0.757	5 (4.9) 17 (14.3)	9 (8.3) 11 (9.2)	0.319
Length of hospital stay, days (median [IQR])	7 [5-12]	7 [6-11]	0.632	7 [5-12]	7 [5-11]	0.906
Readmission[ϕ] *Unknown*	34 (22.5) 1 (0.7)	67 (19.0) 10 (2.8)	0.372	23 (19.5) 1 (0.8)	20 (17.5) 5 (4.2)	0.703
30-day or in-hospital mortality	3 (2.0)	13 (3.6)	0.335	2 (1.7)	4 (3.4)	0.408
Ideal outcome [ϕ] *Unknown*	65 (50.0) 22 (14.5)	170 (52.0) 35 (9.7)	0.701	55 (55.0) 19 (16.0)	61 (58.1) 14 (11.8)	0.655

[ϕ] Percentages do not add up due to missing values.
Values are n (%) unless otherwise indicated.

Abbreviations: e-RLP: robot-assisted extended left-sided pancreatectomy; e-LLP: laparoscopic extended left-sided pancreatectomy; CD: Clavien-Dindo classification; SMD: standardized mean difference; POPF: postoperative pancreatic fistula; PPH: post-pancreatectomy hemorrhage; DGE: delayed gastric emptying; IQR: interquartile range.

Table 4. Pathological outcomes in patients with neoplasms

All patients	**Total cohort**			**Cohort after propensity-score matching**		
	e-RLP (n = 152)	**e-LLP (n = 362)**	**p-value**	**e-RLP (n = 119)**	**e-LLP (n = 119)**	**p-value**
Histopathological diagnosis			0.367			0.862
PDAC	60 (40.5)	144 (40.6)		48 (41.4)	48 (41.0)	
NEN	30 (20.3)	69 (19.4)		20 (17.2)	27 (23.1)	
IPMN	20 (13.5)	27 (7.6)		16 (13.8)	11 (9.4)	
MCN	13 (8.8)	32 (9.0)		10 (8.6)	10 (8.5)	
SPN	5 (3.4)	8 (2.3)		4 (3.4)	4 (3.4)	
Serous cystadenoma	4 (2.7)	10 (2.8)		4 (3.4)	3 (2.6)	
Chronic pancreatitis	6 (4.1)	18 (5.1)		5 (4.3)	3 (2.6)	
Ampullary carcinoma, PBs	-	1 (0.3)		-	-	
Other	10 (6.8)	46 (13.0)		9 (7.8)	11 (9.4)	
Unknown	4 (2.6)	7 (1.9)		3 (2.5)	2 (1.7)	
Patients with PDAC	**e-RLP (n = 60)**	**e-LLP (n = 144)**	**p-value**	**e-RLP (n = 48)**	**e-LLP (n = 48)**	**p-value**
Tumor stage			0.359			0.759
T1	10 (18.5)	14 (11.2)		9 (20.9)	6 (15.0)	
T2	23 (42.6)	51 (40.8)		16 (37.2)	17 (42.5)	
T3	21 (38.9)	57 (45.6)		18 (41.9)	17 (42.5)	
T4	-	3 (2.4)		-	-	
Unknown	6 (10.0)	19 (13.2)		5 (10.4)	8 (16.7)	
Lymph node stage			0.708			0.662
N0	7 (26.9)	22 (22.4)		6 (27.3)	5 (17.2)	
N1	15 (57.7)	54 (55.1)		12 (54.5)	17 (58.6)	
N2	4 (15.4)	22 (22.4)		4 (18.2)	7 (24.1)	
Unknown	34 (56.7)	46 (31.9)		26 (54.2)	19 (39.6)	
M1 stage	4 (10.5)	5 (6.3)	0.669	2 (7.4)	3 (10.7)	>0.999
Unknown	22 (36.7)	65 (45.1)		21 (43.8)	20 (41.7)	
Resected lymph nodes	15 [9-19]	19 [12-27]	**0.020**	14.5 [9-19]	16 [12-23.5]	0.084
Positive lymph nodes	1 [0-2]	1 [0-4]	0.245	1 [0-2]	1 [0-3]	0.342
Resection margin	24 (53.3)	83 (63.4)	0.312			0.606
R0	21 (46.7)	48 (36.6)		18 (52.9)	27 (61.4)	
R1/2	15 (25.0)	13 (9.0)		16 (47.1)	17 (38.6)	

Unknown	4 (7.7)	15 (16.1)		14 (29.2)	4 (8.3)	
Anterior margin	5 (9.6)	15 (16.1)		4 (8.7)	9 (20.9)	
Posterior margin	-	5 (5.4)		5 (10.9)	8 (18.6)	
Transection margin	2 (3.8)	5 (5.4)		-	3 (7.0)	
Vascular margin	6 (11.5)	2 (2.2)		2 (4.3)	1 (2.3)	
Unknown margin				6 (13.0)	1 (2.3)	
Lymphovascular invasion	14 (26.9)	41 (44.1)	0.062	14 (30.4)	19 (44.2)	0.262
Unknown	8 (13.3)	51 (35.4)		2 (4.2)	5 (10.4)	
Perineural invasion	13 (25.0)	45 (48.4)	**0.010**	13 (28.3)	20 (46.5)	0.118
Unknown	8 (13.3)	51 (35.4)		2 (4.2)	5 (10.4)	

$^{\phi}$ Percentages do not add up due to missing values.
Values are n (%) unless otherwise indicated.
Abbreviations: ELP: extended left-sided pancreatectomy; PDAC: pancreatic ductal adenocarcinoma; NEN: neuro-endocrine neoplasm; IPMN: intraductal papillary mucinous neoplasm; MCN: mucinous cystic neoplasm; SPN: solid pseudopapillary neoplasms; PBs: pancreatobiliairy subtype; mm: millimeters; M1 stage: metastasis stage 1.