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RESEARCH

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Effect of differences in vascular anatomy on surgical outcomes of left pancreatectomy: a retrospective study

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Abstract

Background Minimally invasive left pancreatectomy (MILP) is increasingly performed worldwide, necessitating the need for improved understanding of vascular anatomy during surgery. However, the effect of differences in vascular anatomy on surgical outcomes remains unclear. In this study, we aimed to evaluate the effect of vascular anatomical variations on surgical outcomes and identify factors that influence open and minimally invasive surgery (MIS) outcomes.

Methods This was a single-center retrospective study involving 123 patients who underwent left pancreatectomy (LP). We analyzed the correlation between vascular anatomical variations, namely, (i) the root of the splenic artery (SpA; types 1 and 2), (ii) the parent artery of the dorsal pancreatic artery, (iii) confluence patterns of the left gastric vein, and (iv) the inferior mesenteric vein, and surgical outcomes. We also performed a risk analysis of prolonged operation time, considering surgery-related factors.

Results SpA type 2 was only significantly associated with longer operation time ($p < 0.01$) in LP procedures. In all LP cases, the pancreatic resection line (above the portal vein: odds ratio [OR] 3.47; 95% confidence interval [CI] 1.69–11.18; $p < 0.01$), the SpA type (type 2; OR 2.77; 95% CI 1.16–6.94; $p = 0.02$), and surgery type (MIS; OR 5.24; 95% CI 2.17–14.00; $p < 0.001$) were independently associated with prolonged operation times. In open-LP cases, high body mass index (> 24 kg/m^2; OR 7.24; 95% CI 1.89–36.34; $p < 0.01$), tumor location (pancreatic body; OR 6.89; 95% CI 1.79–33.79; $p < 0.01$), and the SpA type (type 2; OR 5.86; 95% CI 1.72–24.65; $p < 0.01$) showed significant association with prolonged operations. In MILP cases, sex (male; OR 9.07; 95% CI 2.61–38.65; $p < 0.001$) and the pancreatic resection line (above the portal vein; OR 4.12; 95% CI 1.18–17.08; $p = 0.03$) showed significant associations.

Conclusions SpA type 2 may negatively affect surgical outcomes. Therefore, it is important to recognize and approach vascular anatomy appropriately. MIS, especially robotic surgery, may be effective in mitigating the negative effects of variations in vascular anatomy.

Keywords Vascular anatomy, Root of the splenic artery, Left pancreatectomy, Minimally invasive surgery, Robotic surgery

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Background

Left pancreatectomy (LP) is a major surgical procedure used to treat pancreatic disease. Although this procedure has the same scope with pancreaticoduodenectomy (PD), it has some differences. Unlike PD, LP does not require complex reconstruction, making it more suitable for minimally invasive surgery (MIS). Consequently, MIS has a shorter performance time and shorter learning curve, hence its widespread acceptance as a standard procedure by hepato-biliary-pancreatic (HBP) surgeons [1–6]. However, LP remains a complex procedure because of various potential anatomical difficulties in the left pancreas and its surrounding structures. As minimally invasive-LP (MILP) is now accepted globally, a better understanding of vascular anatomy is crucial to perform safe surgeries [7]. Nevertheless, there are only few studies on the relationship between anatomical variations and surgical outcomes, thus resulting in unclear effects of differences in vascular anatomy on surgical outcomes [8]. Therefore, in this study, we aimed to evaluate the effect of vascular anatomical variations on surgical outcomes and identify surgical factors that negatively influence outcomes in open-LP (OLP) and MILP to examine the efficacy of MIS in LP.

Methods

Study design, aim, and setting

This was a single-center retrospective study. Here, we aimed to evaluate the effect of vascular anatomical variations on surgical outcomes and identify surgical factors that negatively influence outcomes in OLP and MILP to examine the efficacy of MIS in LP. This retrospective study included patients who underwent LP for pancreatic disease at the Department of Gastroenterological Surgery, Gifu University Hospital, between January 2010 and July 2024. All procedures were performed by expert surgeons certified by the Japanese Society of Hepato-Biliary-Pancreatic Surgery. This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Gifu University (approval number: 2024–102).

Type of surgery

We introduced the laparoscopic surgery for LP in 2012. In accordance with insurance coverage, we first performed the procedure for benign or low-grade malignant tumors. Subsequently, the indication of the laparoscopic surgery in LP was expanded to malignant tumors in 2016. From 2023, regardless of type of disease, all LP surgeries except for cases that required multi-organ resection were performed using robotic-assisted surgery (da Vinci Xi robotic system, Intuitive Surgical, Sunnyvale, CA, USA).

Vascular anatomical variations in LP

We investigated the following vascular anatomical variations by evaluating preoperative contrast-enhanced multi-detector row computed tomography (MDCT) images: (i) the root of the splenic artery (SpA) (type 1: the root of the SpA was positioned upward and not covered by the pancreatic parenchyma; type 2: the root of the SpA was covered ventrally by the pancreatic parenchyma) (Fig. 1), (ii) the parent artery of the dorsal pancreatic artery (DPA), (iii) the confluence patterns of the left gastric vein (LGV), and (iv) the confluence pattern of the inferior mesenteric vein (IMV).

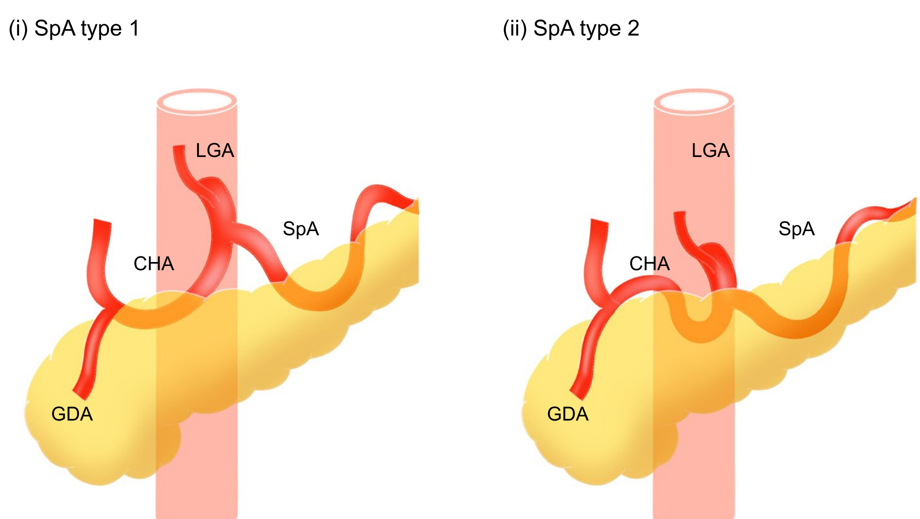

Fig. 1 Two types of the SpA root evaluating preoperative contrast-enhanced MDCT images. **a** SpA type 1: the root of the SpA is positioned upward and not covered by the pancreatic parenchyma. **b** SpA type 2: the root of the SpA is covered ventrally by the pancreatic parenchyma. MDCT, multi-detector row computed tomography; CHA, common hepatic artery; GDA, gastric duodenal artery; LGA, left gastric artery; SpA, splenic artery

Statistical analysis

Fisher's exact test was used to compare categorical variables between groups. For continuous variables, the Mann–Whitney U test and Kruskal–Wallis test were used to compare differences between independent groups. To evaluate risk factors for prolonged operation time, the patients were classified into two groups based on the median operation time. Variables with a p value < 0.05 in the univariate analysis were included in the multivariate logistic regression model. Statistical significance was set at a two-sided p value < 0.05. All statistical analyses were performed using JMP software (SAS Institute Inc., Cary, NC, USA).

Results

Patients

Overall, 167 patients who underwent LP for pancreatic disease were included. We excluded 44 patients who underwent simultaneous resection of other organs, resulting in a final cohort of 123 patients. Of these, 68 (55.3%) underwent OLP, and 55 (44.7%) underwent MILP (Fig. 2), which included 37 laparoscopic cases and 18 robotic cases.

Correlation between surgical outcomes and anatomical variations by surgical procedure of LP

Table 1 shows the summary of the frequency of each vascular anatomical variation observed on preoperative MDCT images and the correlation between these anatomical variations and surgical outcomes (operation time, intraoperative blood loss, and clinically relevant postoperative pancreatic fistula [CR-POPF]) stratified by the surgical procedure of LP.

The SpA was identified in all 123 patients. Regarding the root of the SpA, type 1 was more common in 59.3% (73/123) of patients, while type 2 was present in the remaining 40.7% (50/123 patients). The DPA was identified in 92.7% of patients (114/123 patients). Regarding the parent artery of the DPA, the superior mesenteric artery was the most common and was present in 34.1% (42/123 patients), followed by the SpA in 26.0% (32/123 patients), the common hepatic artery in 17.9% (22/123 patients), and the celiac artery in 14.6% (18/123 patients). The LGV was identified in 94.3% (116/123 patients). Among the confluence patterns of the LGV, the portal vein was observed in 55.3% (68/123 patients) and the splenic vein (SpV) in 39.0% (48/123 patients). The IMV was identified in 99.2% (122/123 patients). Regarding the confluence patterns of the IMV, the superior mesenteric vein was noted in 55.3% (68/123 patients), and the SpV was observed in 43.9% (54/123 patients).

The type of SpA root showed a significant correlation with surgical outcomes in all LP cases. Type 2 was significantly associated with longer operation time ($p < 0.01$) and showed a significant trend toward greater intraoperative blood loss ($p = 0.06$). Interestingly, a

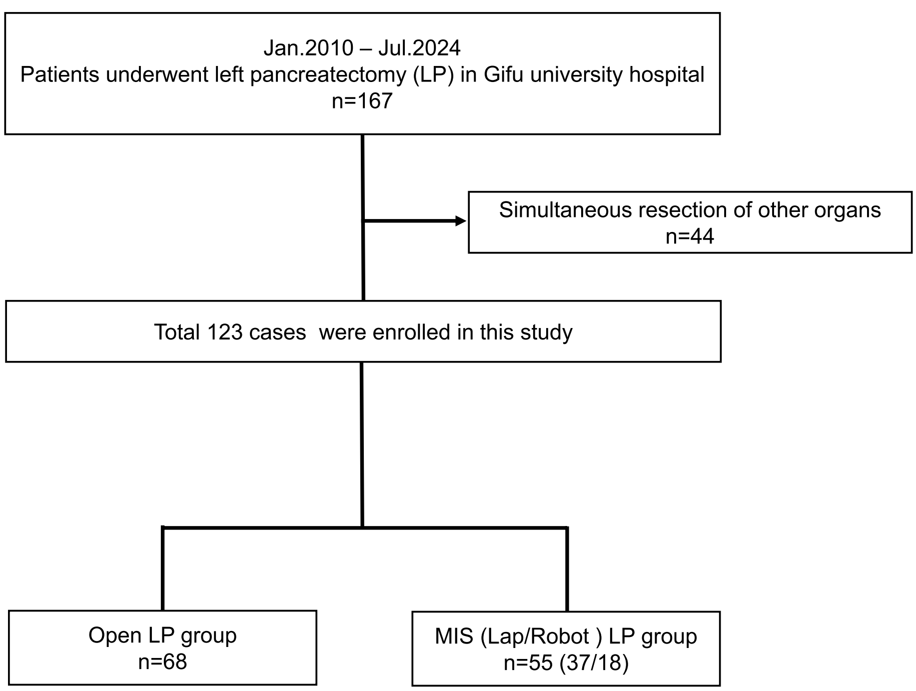

Fig. 2 Exclusion criteria

Table 1 Correlation between surgical outcomes and anatomical variations by surgical procedure of LP

	The root of the SpA			Parent artery of the DPA					Confluence patterns of the LGV			Confluence patterns of the IMV		
	Type1	Type2		SMA	SpA	CHA	CA		PV	SpV		SMV	SpV	
All LP	$n=73$ (59.3%)	$n=50$ (40.7%)	p	$n=42$ (34.1%)	$n=32$ (26.0%)	$n=22$ (17.9%)	$n=18$ (14.6%)	p	$n=68$ (55.3%)	$n=48$ (39.0%)	p	$n=68$ (55.3%)	$n=54$ (43.9%)	p
Operation time (min)	262 [220–299]	288 [247–371]	< 0.01**	255 [218–345]	280 [233–337]	279 [254–370]	285 [245–363]	0.56	273 [225–340]	283 [231–327]	0.74	270 [221–309]	284 [238–376]	0.08
Blood loss (ml)	100 [10–320]	280 [20–670]	0.06	180 [83–563]	263 [13–620]	135 [14–428]	263 [13–620]	0.24	90 [10–330]	190 [10–491]	0.22	135 [16–453]	180 [10–535]	0.73
CR-POPF	16 (21.9%)	7 (14.0%)	0.35	8 (19.1%)	8 (25.0%)	4 (18.2%)	3 (16.7%)	0.88	14 (20.6%)	8 (16.7%)	0.64	14 (20.6%)	9 (16.7%)	0.65
OLP	$n=36$ (52.9%)	$n=32$ (47.1%)	p	$n=27$ (39.7%)	$n=19$ (27.9%)	$n=10$ (14.7%)	$n=8$ (11.8%)	p	$n=34$ (50.0%)	$n=28$ (41.2%)	p	$n=40$ (58.8%)	$n=27$ (39.7%)	p
Operation time (min)	233 [209–270]	285 [236–359]	< 0.01**	246 [218–287]	280 [233–337]	251 [204–305]	262 [229–340]	0.63	262 [215–319]	251 [222–290]	0.71	251 [218–295]	275 [226–331]	0.39
Blood loss (ml)	203 [105–453]	570 [280–780]	< 0.01**	270 [121–585]	400 [255–800]	240 [103–629]	330 [133–623]	0.29	295 [95–640]	278 [183–703]	0.31	285 [130–556]	380 [208–733]	0.19
CR-POPF	12 (33.3%)	6 (18.8%)	0.27	7 (25.9%)	6 (31.6%)	2 (20.0%)	3 (37.5%)	0.85	11 (32.4%)	6 (21.4%)	0.40	12 (30.0%)	6 (22.2%)	0.58
MILP	$n=37$ (67.3%)	$n=18$ (32.7%)	p	$n=15$ (27.3%)	$n=13$ (23.6%)	$n=12$ (21.8%)	$n=10$ (18.2%)	p	$n=34$ (61.8%)	$n=20$ (36.4%)	p	$n=28$ (50.9%)	$n=27$ (49.1%)	p
Operation time (min)	283 [250–366]	311 [272–406]	0.20	294 [210–396]	283 [257–333]	291 [270–380]	332 [259–455]	0.71	277 [242–377]	308 [278–378]	0.23	283 [256–344]	307 [264–440]	0.15
Blood loss (ml)	10 [0–125]	5 [0–58]	0.16	75 [0–230]	5 [0–53]	18 [3–233]	5 [0–23]	0.18	13 [0–81]	8 [0–143]	0.61	10 [0–90]	10 [0–120]	0.58
CR-POPF	4 (10.8%)	1 (5.6%)	1.00	1 (6.7%)	2 (15.4%)	2 (16.7%)	0 (0.0%)	0.51	3 (8.8%)	2 (10.0%)	1.00	2 (7.1%)	3 (11.1%)	0.67

Data are expressed as median (interquartile range) or number of patients (percentage)

SpA splenic artery, *DPA* dorsal pancreatic artery, *SMA* superior mesenteric artery, *CHA* common hepatic artery, *CA* celiac artery, *LGV* left gastric vein, *PV* portal vein

SpV splenic vein, *IMV* inferior mesenteric vein, *SMV* superior mesenteric vein

CR-POPF clinically relevant postoperative pancreatic fistula

* $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

more significant correlation between anatomical variation and surgical outcomes was observed in the OLP group, and no significant difference was noted in the MILP group. With regard to CR-POPF, no significant correlation with vascular anatomical variation was demonstrated in any of types of surgery.

Univariate and multivariate analyses of risk factors for prolonged operation time in all LP cases

Table 2 shows the results of univariate and multivariate analyses of the risk factors for prolonged operation time in all LP cases (median operation time: 276 [228–337] min). The univariate analysis identified significant associations between prolonged operation time and the

Table 2 Univariate and multivariate analysis of risk factors for long operation time in all LP cases

	n	Univariate			Multivariate		
		OR	95%CI	*p*-value	OR	95%CI	*p*-value
Age (years)			0.70–3.06	0.32			
> 70	49	1.45					
< 70	74	1					
Sex		1.04	0.651–2.14	0.90			
Male	64	1					
Female	59						
BMI (kg/m^2)			0.98–4.81	0.06			
> 24	40	2.12					
< 24	83	1					
ASA-PS			0.30–1.92	0.55			
1	23	0.75					
2/3	100	1					
Pancreatic cancer		1.64	0.80–3.40	0.18			
Yes	58	1					
No	65						
Tumor location		1.35	0.66–2.78	0.41			
Body	66	1					
Tail	57						
Pancreatic resection line		3.47	1.64–7.55	< 0.01**		1.69–11.18	< 0.01**
Portal vein	75	1			4.18		
Left side of aorta	48				1		
Spleen preservation		0.60	0.22–1.56	0.29			
Yes	20	1					
No	103						
The root of the SpA		1	1.42–6.71	< 0.01**		1.16–6.94	0.02*
Type1	73	3.03			1		
Type2	50				2.77		
Texture of the pancreatic parenchyma		0.77	0.35–1.68	0.51			
Hard	54	1					
Soft	69						
Type of surgery			1.32–5.92	< 0.01**		2.17–14.00	< 0.001***
Open	68	1			1		
MIS	55	2.76			5.24		

LP left pancreatectomy, *MIS* minimally invasive surgery, *BMI* body mass index, *ASA-PS* American Society of Anesthesiologists physical status classification system, *SpA* splenic artery

The root of the SpA:

Type1 [in which the root of the SpA was upward and not covered by the pancreatic parenchyma]

Type2 [in which the root of the SpA was ventrally covered by the pancreatic parenchyma]

* $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

pancreatic resection line, root of the SpA pattern, and type of surgery (all $p < 0.01$). Multivariate logistic regression analysis revealed that the pancreatic resection line (above the portal vein: odds ratio [OR] 3.47; 95% confidence interval [CI] 1.69–11.18; $p < 0.01$), the root of the SpA pattern (type 2; OR 2.77; 95% CI 1.16–6.94; $p = 0.02$), and type of surgery (MIS; OR 5.24; 95% CI 2.17–14.00; $p < 0.001$) were independently associated with prolonged operation times in all LP cases.

Comparison of patient characteristics between the OLP and MILP groups

The findings of the comparison of patient characteristics between the OLP and MILP groups are shown in Supplemental Table 1. Compared to the MILP group, the OLP group had a significantly higher proportion of patients with cancer (58.8% vs. 34.5%, $p = 0.01$), pancreatic body tumors (67.6% vs. 36.4%, $p < 0.001$), and cases of pancreatic resections involving the area above the portal vein (69.1% vs. 50.9%, $p = 0.04$). On the other hand, the MILP group had a significantly higher proportion of cases with spleen preservation (25.5% vs. 8.8%, $p = 0.01$) and soft pancreas (70.9% vs. 44.1%, $p < 0.001$).

Regarding surgical outcomes, the MILP group experienced a significantly longer median operative time (294 min vs. 255 min, $p < 0.01$), but had less median intraoperative blood loss (10 ml vs. 300 ml, $p < 0.001$), a lower incidence of clinically relevant postoperative pancreatic fistula (9.1% vs. 26.5%, $p = 0.02$), and a shorter median postoperative hospital stay (13 days vs. 14 days, $p = 0.03$) than the OLP group.

Univariate and multivariate analyses of risk factors for prolonged operation time in OLP cases

Table 3 shows the results of univariate and multivariate analyses of risk factors for prolonged operation time in OLP cases. In the univariate analysis, prolonged operation time in OLP cases was significantly associated with body mass index (BMI) ($p < 0.01$), tumor location ($p = 0.04$), and the root of the SpA pattern ($p = 0.02$). Multivariate logistic regression analysis revealed that high BMI (> 24; OR 7.24; 95% CI 1.89–36.34; $p < 0.01$), tumor location (pancreatic body; OR 6.89; 95% CI 1.79–33.79; $p < 0.01$), and the root of the SpA pattern (type 2; OR 5.86; 95% CI 1.72–24.65; $p < 0.01$) were independently associated with prolonged operation times in OLP cases.

Univariate and multivariate analyses of risk factors for prolonged operation time in MILP cases

Table 4 presents the results of univariate and multivariate analyses of risk factors for prolonged operation time in patients with MILP. In the univariate analysis, prolonged operation time in MILP cases was significantly associated with sex ($p < 0.001$) and the pancreatic resection line ($p = 0.04$). Multivariate logistic regression analysis revealed that sex (male; OR 9.07; 95% CI 2.61–38.65; $p < 0.001$) and the pancreatic resection line (above the portal vein; OR 4.12; 95% CI 1.18–17.08; $p = 0.03$) were independently associated with prolonged operation times in MILP cases.

Discussion

In recent years, MIS has emerged as a standard approach in gastroenterological surgery, a trend that is also observed in the complex and challenging HBP procedure. This is particularly true for LP, as the surgical procedures are relatively easy to standardize. The first laparoscopic-LP (LLP) and robot-assisted-LP (RLP) were performed by Gagner et al. [9] in 1996 and Giulianotti et al. [10] in 2003, respectively. Since then, MILP, which is a combination of both procedures, has become widespread. Given this expansion, the demand for a comprehensive understanding of surgical anatomy has also grown to ensure safe and accurate procedures. To address this, the "Precision Anatomy for Minimally Invasive Hepato-Billiary-Pancreatic surgery (PAM-HBP surgery) Expert Consensus Meeting," held in Tokyo in 2021 with the participation of international HBP surgeons, aimed at developing recommendations on the anatomical landmarks essential for safe MIS. In preparation for this meeting, Nishino et al. [7] conducted a systematic review to evaluate the available literature on "precision anatomy for MILP," with a focus on patterns and validations of peripancreatic vascular structures that could serve as key anatomical landmarks for performing MILP safely. Although there have been previous reports on the impact of perioperative factors (such as BMI, visceral fat, malignant disease, multi-organ resection, past abdominal surgery, pancreatic resection line, and surgeon' experience) on surgical outcomes [11–16], only few studies have evaluated the effects of vascular anatomy on surgical outcomes following LP [8, 17]. Therefore, in this study, we evaluated the impact of vascular anatomy variations in LP on surgical outcomes. The results showed that only the type of root of the SpA was significantly correlated with operative time and intraoperative blood loss in relation to the variations in peripancreatic vascular structures. Furthermore, this is the first study to discover that this correlation was stronger in the open surgery group than in the MIS group.

In this study, we investigated the frequency of typical vascular anatomical variations directly related to surgical procedures in LP, such as (i) the root of the SpA, (ii) parent artery of the DPA, (iii) confluence patterns of the LGV, and (iv) confluence patterns of the IMV. The results were consistent with those from a systematic review by

Table 3 Univariate and multivariate analysis of risk factors for long operation time in OLP cases

	n	Univariate			Multivariate		
		OR	95%CI	*p*-value	OR	95%CI	*p*-value
Age (years)			0.23–1.65	0.34			
> 70	30	0.62					
< 70	38	1					
Sex		2	0.74–5.50	0.17			
Male	39	1					
Female	37						
BMI (kg/m^2)			1.48–18.29	< 0.01**			< 0.01**
> 24	22	4.70			7.24	1.89–36.34	
< 24	46	1			1		
ASA-PS			0.11–2.04	0.32			
1	10	0.49					
2/3	58	1					
Pancreatic cancer		0.72	0.26–1.94	0.52			
Yes	39	1					
No	29						
Tumor location		3.25	1.08–11.28	0.04*			< 0.01**
Body	45	1			6.89	1.79–33.79	
Tail	23				1		
Pancreatic resection line		1.55	0.54–4.45	0.41			
Portal vein	47	1					
Left side of aorta	21						
Spleen preservation		3.71	0.55–73.39	0.19			
Yes	6	1					
No	62						
The root of the SpA			1.17–9.45	0.02*		1.72–24.65	< 0.01**
Type1	37	1			1		
Type2	31	3.21			5.86		
Texture of the pancreatic parenchyma			0.20–1.70	0.33			
Hard	38	0.59					
Soft	30	1					

LP left pancreatectomy, *MIS* minimally invasive surgery, *BMI* body mass index, *ASA-PS* American Society of Anesthesiologists physical status classification system, *SpA* splenic artery

The root of the SpA:

Type1 [in which the root of the SpA was upward and not covered by the pancreatic parenchyma]

Type2 [in which the root of the SpA was ventrally covered by the pancreatic parenchyma]

* $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

PAM-HBP surgery [7]. Previous studies reported that SpA type 2 was observed in 33.3%–62.0% of the cases [7, 8, 17–19]. In a multivariate analysis, Ishikawa et al. [8] reported that SpA type 2 was an independent risk factor for longer operative times and was associated with increased intraoperative blood loss in 34 LP cases. Nakata et al. [17] also reported that SpA type 2 was associated with a significantly longer median operative time than type 1 (285.0 min vs. 235.5 min, $p < 0.01$) in 50 LP cases. We had similar findings in our study; this implies that the increased difficulty in isolating the SpA might have been due to this anatomical variation, contributing to longer operative times. We hypothesized that the DPA (especially the type that originated from the SpA), the LGV, and the IMV (especially the type of confluence into the SpV) would affect surgical outcomes as well as the SpA. However, only the confluence pattern of the IMV showed a significant correlation with operative time in all LP cases. Although these vascular anatomical variations did not show significant differences singularly in

Table 4 Univariate and multivariate analysis of risk factors for long operation time in MILP cases

	n	Univariate			Multivariate		
		OR	95%CI	*p*-value	OR	95%CI	*p*-value
Age (years)			0.36–3.43	0.85			
> 70	19	1.11					
< 70	36	1					
Sex		7.39	2.33–26.48	< 0.001***		2.61–38.65	< 0.001***
Male	25	1			9.07		
Female	30				1		
BMI (kg/m^2)			0.63–6.46	0.25			
> 24	18	1.96					
< 24	37	1					
ASA-PS	13		0.14–1.81	0.30			
1	42	0.52					
2/3		1					
Pancreatic cancer		2.14	0.70–6.98	0.18			
Yes	19	1					
No	36						
Tumor location		2.48	0.81–8.05	0.11			
Body	35	1					
Tail	20						
Pancreatic resection line		3.06	1.04–9.51	0.04*		1.18–17.08	0.03*
Portal vein	28	1			4.12		
Left side of aorta	27				1		
Spleen preservation		0.43	0.12–1.49	0.19			
Yes	11	1					
No	44						
The root of the SpA			0.60–6.04	0.29			
Type1	37	1					
Type2	18	1.85					
Texture of the pancreatic parenchyma			0.18–2.64	0.64			
Hard	16	0.71					
Soft	39	1					

LP left pancreatectomy, *MIS* minimally invasive surgery, *BMI* body mass index, *ASA-PS* American Society of Anesthesiologists physical status classification system, *SpA* splenic artery

The root of the SpA:

Type1 [in which the root of the SpA was upward and not covered by the pancreatic parenchyma]

Type2 [in which the root of the SpA was ventrally covered by the pancreatic parenchyma]

* $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

this study, it is possible that a combination of vascular anatomical variations may have an impact on surgical outcomes.

In this study, we found that the negative impact of anatomical variation in the SpA on surgical outcomes was more pronounced in the open surgery group. We speculate that this is because, during open surgery, the root of the SpA can only be accessed from the ventral direction. Meanwhile, in MIS, the SpA can be approached from both the ventral and craniocaudal direction when viewing magnified high-definition laparoscopic images, making its isolation easier.

Previous studies have suggested that variations in the relationship between the SpA and the pancreatic parenchyma should ideally be used to guide the surgical approach during MILP for safety reasons [5, 8, 20–25]. However, SpA isolation is still considered a difficult procedure in LLP because the forceps can only be manipulated in a linear fashion. A previous report on LLP inferred that based on the time required for

SpA isolation, compared to type 1, the type 2 variation might be more difficult to isolate (27.0 min vs. 7.0 min, $p < 0.001$) [17]. In contrast, robotic surgery, which allows free and precise forceps manipulation, may be easier to successfully perform than LLP, with the surgical approach being adjusted according to each anatomical variation. Based on their experience with 20 RLP cases, Takagi et al. proposed selecting a surgical approach tailored to the anatomical pattern of the SpA to enhance procedural safety [18]. With SpA type 1, the root of the artery can be isolated using an anterior approach, with ligation performed first (SpA-first ligation technique). The pancreas is then divided, followed by the division of the SpA and SpV. However, with SpA type 2, the pancreas is divided first (pancreas-first division technique), which facilitates better access to the splenic vessels. We adopted these same strategies for RLP, which may explain why the SpA pattern was not a risk factor for prolonged operative time in MILP in this study. This study is the first to demonstrate that MIS, especially RLP, may have the potential to mitigate the negative impact of anatomical variations of the splenic vessels during LP.

This study has some limitations. This was a single-center retrospective study with a small sample size, which may have introduced selection bias and issues related to statistical multiplicity. Additionally, the proportion of cancer cases was higher in the OLP group. One reason for this is that LLP for benign diseases and low-grade tumors has been covered by insurance in Japan since 2012, while LLP for malignant tumors became covered by insurance in 2016. On the other hand, RLP had already been covered by insurance for surgery for malignant tumors since its introduction. Thus, the percentage of cancer cases in the RLP group was comparable to that in the OLP group. These limitations should be considered when interpreting the study's results. To achieve more reliable results, a prospective multicenter study with a larger number of patients is necessary.

Conclusions

SpA type 2 may negatively affect surgical outcomes. Therefore, preoperatively recognizing and appropriately approaching vascular anatomy are crucial. MIS allows for adaptable surgical strategies based on individual cases and may be an effective approach to mitigate the negative impact associated with anatomical variations.

Abbreviations

MILP	Minimally invasive left pancreatectomy
MIS	Minimally invasive surgery
CR-POPF	Clinically relevant postoperative pancreatic fistula
SpA	Splenic artery
DPA	Dorsal pancreatic artery
LGV	Left gastric vein
IMV	Inferior mesenteric vein
OR	Odds ratio
CI	Confidence interval
ODP	Open-DP
BMI	Body mass index
MDCT	Multi-detector row computed tomography
HBP	Hepato-biliary-pancreatic
PAM-HBP	Precision anatomy for minimally invasive-HBP
SpV	Splenic vein
LLP	Laparoscopic left pancreatectomy
RLP	Robotic left pancreatectomy
OLP	Open-LP
LP	Left pancreatectomy

Supplementary Information

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Supplementary Material 1

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Authors' contributions

Masahiro Fukada conceived the study concept, planned the study design as the principal investigator, interpreted the results, and drafted the manuscript. Nobuhisa Matsuhashi revised the manuscript by adding intellectual content and providing critical advice. Masahiro Fukada, Noriki Mitsui, Takeshi Horaguchi, Yuji Hatanaka, Itaru Yasufuku, Yuta Sato, Jesse Yu Tajima, Sigeru Kiyama, Yoshihiro Tanaka, Katsutoshi Murase, and Nobuhisa Matsuhashi obtained the data, provided critical comments to improve the manuscript, and approved the final submission of this manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Gifu University (approval number: 2024–102). Given the retrospective nature of this study and the exclusion of any potentially identifiable patient data, the requirement for informed consent was waived by the Ethics Committee of Gifu University.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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