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ORIGINAL ARTICLE

Laparoscopic versus open radical antegrade modular pancreatosplenectomy with artery–first approach in pancreatic cancer

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Abstract

Background An artery-first approach for pancreatic cancer (PC) is challenging to perform laparoscopically and is mainly performed using an open approach. The aims of this study were to assess the safety and feasibility of laparoscopic radical antegrade modular pancreatosplenectomy (RAMPS) with an artery-first approach (L-aRAMPS) as compared with open aRAMPS (O-aRAMPS) in resectable PC using matched-pair analysis.

Methods Artery-first approach is an early dissection of the superior mesenteric artery (SMA) from behind the pancreas body as the first surgical step. Data on L-aRAMPS and O-aRAMPS, performed between July 2013 and November 2019, were collected retrospectively. Additionally, the spatial characteristics of the splenic artery were analyzed using computed tomography.

Results Thirty L-aRAMPS and 33 O-aRAMPS for resectable PC were included. After matching, 15 L-aRAMPS were compared with 15 O-aRAMPS. Median intraoperative blood loss and hospital stay were significantly improved in L-aRAMPS compared to O-aRAMPS (30 vs. 220 g, $p < 0.001$; 12 vs. 16 days, $p = 0.049$). The overall morbidity was similar in both study groups. The total number of lymph nodes dissected and those harvested from around the SMA and R0 resection was similar in both study groups. We classified the width of the cross section of the pancreas body into three equal parts: the upper, middle, and lower parts of the pancreas; 63% of the splenic artery origin was located in middle and lower parts of the pancreas body.

Conclusion L-aRAMPS is technically safe and oncologically feasible to secure favorable surgical outcomes for resectable PC patients.

Keywords Laparoscopic radical antegrade modular pancreatosplenectomy · Artery-first approach · Superior mesenteric artery · Splenic artery · Pancreatic cancer · Propensity score matching

Introduction

Laparoscopic distal pancreatectomy (LDP) was first reported in 1994 [1] and has become a safe and effective surgical option for benign and borderline malignant disorders of the pancreas [2–6]. The advantages of LDP were evaluated in terms of intraoperative blood loss, surgical site infection, and length of hospital stay as compared to open distal pancreatectomy [2–6], but the oncological benefits of LDP for cancers of the body and tail of the pancreas remain a controversial issue [7, 8].

In general, the standard surgical approach for cancers of the body and tail of the pancreas has been open distal pancreatectomy with en bloc regional lymph node dissection. Radical antegrade modular pancreatosplenectomy (RAMPS), an advanced surgical approach introduced by Strasberg et al. [9] and Grossman et al. [10], has provided an improvement in surgical field visibility, proper adjustment of the depth of the posterior extent of the resection according to the depth to the rear outline of the tumor, early vascular control, and oncological benefits.

On the other hand, an early dissection of the superior mesenteric artery (SMA) from behind the head to the body of the pancreas using the artery-first approach has been recognized as an effective technique in performing a pancreaticoduodenectomy [11–14] or pancreatosplenectomy

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[15] for pancreatic cancer. The advantage of the artery-first approach is a complete tumor clearance at the resection margin (R0) around the major vessels [11–15]. The R0 resection is recognized as a significant prognostic factor in pancreatic cancer [16], and we first reported a modified RAMPS technique utilizing the artery-first approach (aRAMPS) to secure negative surgical margins with favorable outcomes in 2015 [15]. Despite these experiences and observations, at this point, clinical evidence with regard to the safety and feasibility of laparoscopic aRAMPS (L-aRAMPS) is still lacking. The aims of this study were to present our challenging laparoscopic technique and to assess the safety and feasibility of L-aRAMPS for resectable pancreatic cancer patients, focusing on the short-term outcome, including pathologic results, as well as the anatomical features around the pancreas body, in comparison with open aRAMPS (O-aRAMPS) using a propensity score matching analysis.

Methods

Study patients

Between July 2013 and November 2019, 82 consecutive patients underwent aRAMPS for cancer of the body or tail of the pancreas at our hospital. Nineteen patients were excluded from the study because these were borderline resectable or locally advanced cases. Finally, 63 patients with resectable pancreatic cancer underwent aRAMPS procedure. Of these, 33 patients underwent O-aRAMPS [15], while 30 patients received L-aRAMPS for resectable pancreatic cancer. A matched-pair control group consisted of 30 patients, including 15 patients with O-aRAMPS and 15 patients with L-aRAMPS. The operation was carried out by three consulting surgeons (YK, HH, and YT), and the L-aRAMPS procedure was conducted by YK in all cases. Preoperative assessment of tumor staging and resectability was carried out using multidetector computed tomography (CT) with three-dimensional (3D) CT angiography, contrast-enhanced magnetic resonance imaging (MRI), endoscopic ultrasonography (EUS), and/or positron emission tomography (PET). The study was approved by the Ethics Committee of Shimane University Hospital prior to collecting identifiable patient information and analysis (20180325-3), and informed consent was obtained from each participating patient prior to surgery.

Indication of L-aRAMPS for pancreatic cancer

In January 2017, we introduced L-aRAMPS for select patients with resectable cancer of the body or tail of the pancreas. The indication criteria for L-aRAMPS for resectable pancreatic cancer were based on the Yonsei criteria [17] and were as follows: (1) tumors confined to the body or tail of the pancreas and located at least 1 cm away from the celiac axis and (2) tumors with an intact fascial layer between the pancreas and the left adrenal gland and kidney. Patients were discussed among the institutional cancer multidisciplinary team, and a treatment decision was made.

Surgical technique of L-aRAMPS

The oncosurgical principle of L-aRAMPS is based on the a-RAMPS [15] in which an early dissection of the SMA and celiac axis from behind the body of the pancreas is secured as the first step of the operation. This process enables us to ensure resectability and clearance of the lymph nodes around the major vessels.

The patient is placed in the reverse Trendelenburg position with legs apart. The operator is positioned to the right side of the patient, and the first assistant stands on the opposite side. The laparoscopist is positioned between the patient's legs. Five trocars, which are placed in a U shape on the upper abdominal region, are used for the laparoscopic approach. First, to secure the posterior surgical margin, the retroperitoneum is opened at the left side of the duodenojejunal flexure, and the body of the pancreas with the SMA is sufficiently mobilized so that the anterior surface of the aorta, inferior vena cave, left renal vein, left adrenal grand, and kidney are completely exposed; i.e., the anterior RAMPS is performed. If an infiltration of the tumor to the left adrenal gland is suspected, the posterior RAMPS procedure is applied on the anterior surface of the aorta from behind the left renal vein to the posterior aspect of the left adrenal gland. An interaortocaval lymph node sampling is routinely performed. After completing the preparation of the posterior margin, the gastrocolic and gastrosplenic ligaments are divided, and the anterior surface of the body and tail of the pancreas is exposed. The posterior wall of the stomach is then lifted up to the abdominal wall with stitches. To approach the SMA, we dissect the inferior border of the pancreas from the transverse colon mesentery on the neck of the pancreas and then carefully expose the anterior surface of the portal venous system from the posterior aspect of the head of the pancreas (Fig. 1). The right anterior surface of the SMA is safely identified at the left aspect of the superior mesenteric vein (SMV) following preparation of the portal venous system. Intraoperative ultrasonography is helpful to identify the SMV and SMA, and it facilitates this surgical step. The dissection between the body of the pancreas and the SMA should be carefully carried out up to the origin of the SMA under a magnified view from the caudal side. At this step, complete lymphadenectomy from the anterior to the left semicircle aspect of the SMA can be safely performed, and then the posterior margin of the pancreas around the SMA is finally linked to the layer of the anterior RAMPS. When the dorsal pancreatic artery diverges from the SMA, it should be dissected [15]. After preparation of the origin of the SMA, the bifurcation of the splenic artery (SPA) and common hepatic artery is safely

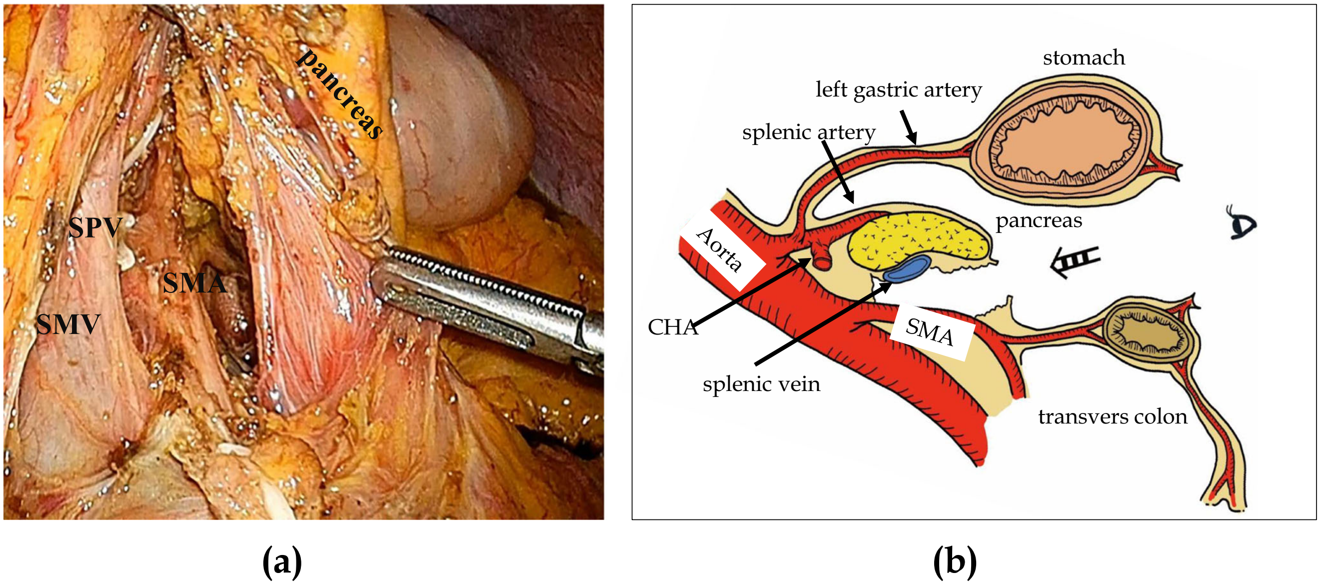


Fig. 1 An intraoperative laparoscopic view demonstrating the approach to the SMA at the inferior border of the neck of the pancreas (**a**). An intraoperative diagram demonstrating an approach to the SMA (**b**). SPV, splenic vein; SMV, superior mesenteric vein; SMA, superior mesenteric artery; CHA, common hepatic artery

identified behind the body of the pancreas under a magnified view via the laparoscopic caudal approach (Fig. 2). The SPA usually stretches perpendicularly from the celiac axis, and its origin is easily secured. The nerve plexus around the SMA (PLsma) and celiac axis (PLce) should be preserved as much as possible under the strict guidance of frozen section analysis [15].

After confirming a cancer-free margin on the posterior aspect of the body of the pancreas near the SMA and celiac axis, attention is directed toward the superior border of the pancreas. Lymphadenectomy is carried out in a median-to-lateral direction, from the hepatic arteries to the SPA, including the left gastric artery and celiac axis. After preparation around these major vessels, the origin of the SPA is clipped with a Hem-o-lok® Ligation System (Teleflex Medical, Boston, MA, USA) and divided. Subsequently, the splenic vein is prepared at the junction with the SMV and can be safely divided, since the arterial inflow has already been blocked. An appropriate transection line for the pancreas is evaluated using intraoperative ultrasonography, and the

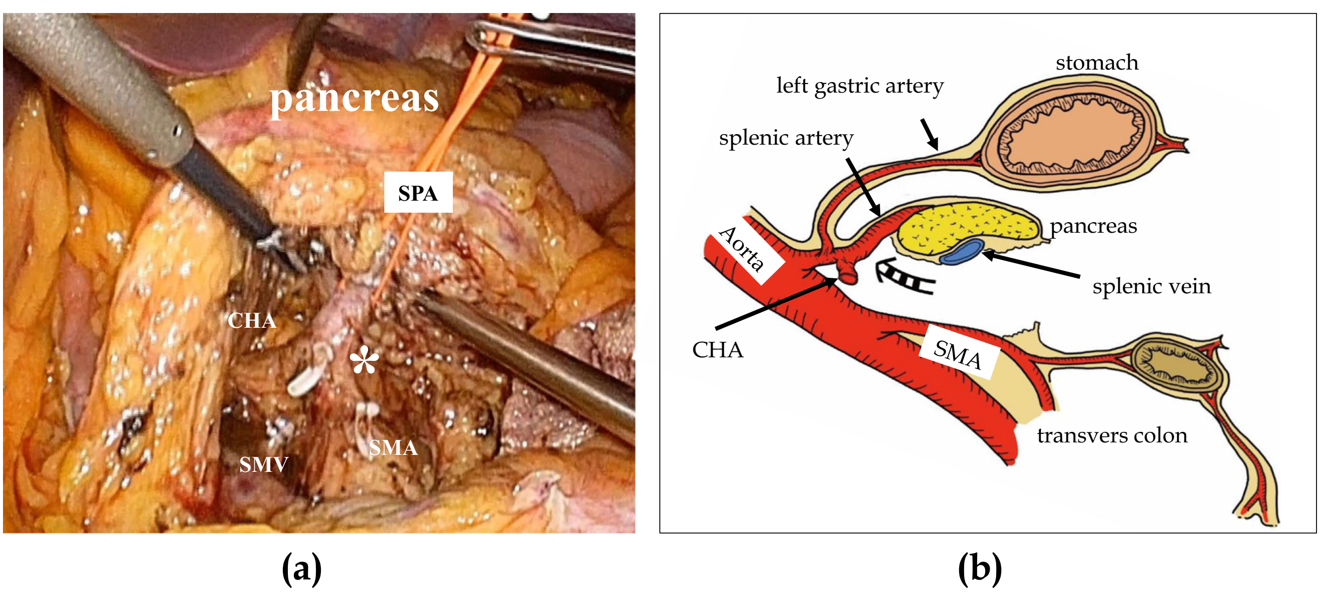


Fig. 2 An intraoperative laparoscopic view demonstrating the operative field after completion of the SMA-first approach around the origin of the SPA and common hepatic artery (**a**). An intraoperative diagram demonstrating an approach to the origin of the SPA (**b**). *, celiac axis; CHA, common hepatic artery; SMA, superior mesenteric artery; SMV, superior mesenteric vein; SPA, splenic artery

pancreas is transected with an endoscopic linear stapler (Echelon Endopath™ Stapler, Ethicon Endo Surgery, Inc., Cincinnati, OH, USA). Although hemostasis on the cut end of the remnant pancreas is usually achieved with gauze compression, active bleeding should be controlled using 5-0 nonabsorbable monofilament sutures.

After transecting the pancreas, dissection of the retroperitoneal tissue, including the inferior mesenteric vein and Gerota's fascia, continues around the tail of the pancreas and spleen. After completion of the distal pancreatectomy with en bloc lymph node dissection, the specimen is bagged and retrieved through the umbilicus with a minimal port-site incision. Two closed drains are placed, anterior and posterior to the pancreatic stump.

Anatomical evaluation of the SPA

To clarify the impact of the artery-first approach in the laparoscopic RAMPS procedure, we investigated the anatomic relationship of the SPA and the pancreas. Two hundred and fourteen patients with hepatobiliary pancreatic disease who underwent multidetector CT with 3D CT angiography using intravenous contrast were evaluated. Multidetector CT was performed using a 320-row CT system (Aquilion ONE; Cannon Medical Systems Corporation, Otawara, Japan). Using these 3D CT angiograms, the distance between the celiac axis origin and the SPA origin, the thickness and width of the cross section of the pancreas body, and the distance between the upper margin of the pancreas body and the SPA origin were measured (Fig. 3).

Pathologic evaluation

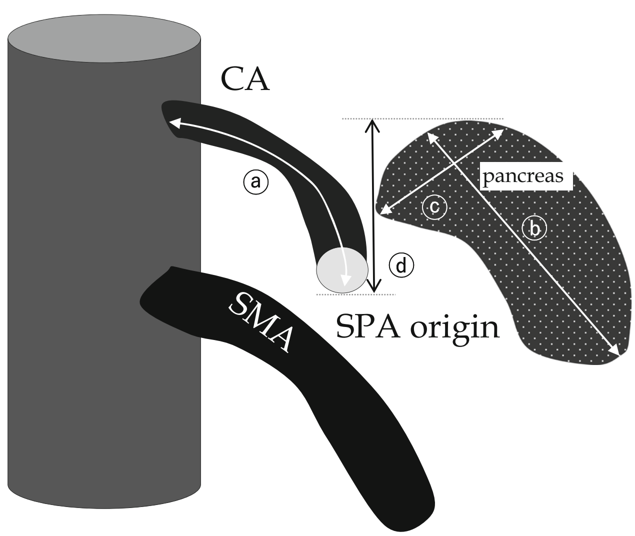
After removal of the surgical specimen, the operating surgeon inked surgical margins on the specimen, i.e., the SMA margin and the posterior margin, on the back table [15]. Formalin-fixed, paraffin-embedded tissue sections were evaluated by two experienced pathologists. The final surgical margin status was coded as "R0" when the resection margins were free from cancer involvement or as "R1" or "R2" if tumor cells were present microscopically or macroscopically at any margin of the surgical specimen, respectively.

Propensity score matching

We adopted a statistical matching technique, and propensity score matching with inverse probability weighting was implemented to reduce the possibility of selection bias on surgical approach. Age, sex, body mass index, tumor location, and T stage at diagnosis were used as the criteria to estimate the propensity scores. The patients with L-aRAMPS were matched to O-aRAMPS based on scores from the algorithm of the nearest neighbor and 1:1 matching without specific caliper width or replacement.

Statistical analysis

Continuous data are presented as a median (range), and categorical data are expressed as a number (percentage). Differences between the frequencies were examined using the chi-square test and two-tailed Fisher's exact test as appro-



	ⓐ	ⓑ	ⓒ	ⓓ
mm, median(range)	37.7(16.4-81.9)	30.4(9.6-73.8)	16.7(6.2-30.1)	11.9(-19.7-39.6)

Fig. 3 The anatomical characteristics between the SPA and the pancreas: ⓐ, total length of the celiac axis; ⓑ, width of the pancreas body; ⓒ, thickness of the pancreas body; ⓓ, distance between the upper margin of the pancreas body and the SPA origin

priate. A two-sample Student's *t* test and Wilcoxon rank sum test were applied for normally and abnormally distributed continuous data, respectively.

The propensity score was calculated by using logistic regression analysis. Overall survival curves were constructed using the Kaplan–Meier technique and compared using the log-rank test. The JMP software program (ver. 14.1; SAS Institute, Inc., Cary, NC, USA) was used for all statistical analyses. Probability (p) values of < 0.05 were considered significant.

Results

The anatomic relationship of the SPA and the pancreas was analyzed from CT images (Fig. 3). The median distance between the celiac axis origin and the SPA origin was 37.7 mm (range 16.4–81.9), and the median values of the thickness and width of the cross section of the pancreas body were 16.7 mm (range 6.2–30.1) and 30.4 mm (range 9.6–73.8), respectively. The SPA origin was located above the upper border of the pancreas body in 32 cases (14.9%) and below the lower border of the pancreas body in 6 cases (2.8%). We classified the width of the cross section of the pancreas body into three equal parts: the upper part, middle part, and lower part of the pancreas (Fig. 4). The SPA origin was located in the upper part, middle part, and lower part in 79 cases (37.1%), 94 cases (44.1%), and 40 cases (18.8%), respectively.

Staging laparoscopy revealed peritoneal dissemination and/or liver metastasis in five cases in the O-aRAMPS group and two in the L-aRAMPS group, and these patients were excluded from this study. After the artery-first approach, RAMPS was successfully completed in the remaining 63 patients. Finally, the diagnostic performance rate for preoperative images in resectable cancer of the body or tail of the pancreas was 90%. The demographic and intraoperative characteristics of patients in the two study groups, i.e., O-aRAMPS and L-aRAMPS, are shown in Table 1. The two study groups were similar with regard to the patients' background. Although the distribution of posterior RAMPS was higher in the O-aRAMPS group than in the L-aRAMPS group in unmatched-pair analysis, there was no significant difference between operative procedures after matched-pair analysis. The median intraoperative blood loss was significantly lower in the L-aRAMPS group than in the O-aRAMPS group (18 g, range 0–180 g, vs. 215 g, range 30–1030 g, $p < 0.001$; 30 g, range 0–100 g, vs. 220 g, range 40–1030 g, $p < 0.001$) in both analyses. No patients required blood transfusion in this study.

Postoperative outcomes are shown in Table 2. There were no hospital deaths or reoperations in this study. The duration of abdominal drain placement and time to resumption of oral intake did not differ between the two study groups. The median hospital stay was significantly shorter in the L-aRAMPS group than in the O-aRAMPS group (12 days, range 8–35 days, vs. 16 days, range 8–96 days, $p = 0.049$) in matched-pair analysis. The overall morbidity, including the postoperative pancreatic fistula (POPF), delayed gastric emptying (DGE), and surgical site infection (SSI), was similar in both groups. No patients had postoperative hemorrhage in this study.

Table 3 shows the tumor characteristics and pathological outcomes. In unmatched- and matched-pair analyses, the tumor stage was similar in this study based on the Union for International Cancer Control (UICC) classification [18]. The definitive pathological examination revealed that the total number of lymph nodes dissected and those harvested from around the SMA was similar in both study groups in both analyses. The rates of lymph node metastasis were similar in the two study groups after matched-pair analysis. R0 resection was similar in the two study groups, and R2 resection was not observed in this study. There were no significant differences in the rates of adjuvant chemotherapy (AC) and the time to AC initiation in the two study groups. The median follow-up period was 12.2 months in the L-aRAMPS group and 36.4 months in the O-aRAMPS group. The relapse-free survival at 2 years was 92.9% in the L-aRAMPS group and 62.5% in the O-aRAMPS group ($p = 0.310$) (Fig. 5). The overall survival rate at 2 years was 90.9% in the L-aRAMPS group and 78.9% in the O-aRAMPS group ($p = 0.819$).

Discussion

LDP has become a safe and feasible surgical option for various pancreatic disorders, including malignancy [2–6, 17]. Recent studies have demonstrated the oncological benefits of laparoscopic RAMPS [17, 19–22] and open RAMPS with an SMA-first approach [15] in the management of cancers of the body or tail of the pancreas. However, the technical safety and oncological feasibility of laparoscopic RAMPS with an artery-first approach remain unclear.

In the present study, the intraoperative blood loss and postoperative hospital stay in L-aRAMPS were significantly improved in comparison with those in O-aRAMPS according to a matched-pair analysis. Furthermore, the occurrence of postoperative complications, including POPF, DGE, and SSI, was similar [23]. These findings are compatible with the results of previous reports on laparoscopic versus open distal pancreatectomy for benign and malignant lesions of the pancreas [2–6]. In L-aRAMPS, which involves challenging laparoscopic and artery-first techniques, severe intraoperative events, e.g., massive bleeding, injury to major vessels, and dissecting aneurysm of the SMA, were not observed. As a result, no patients required conversion to open surgery. These results suggest that our laparoscopic RAMPS with an

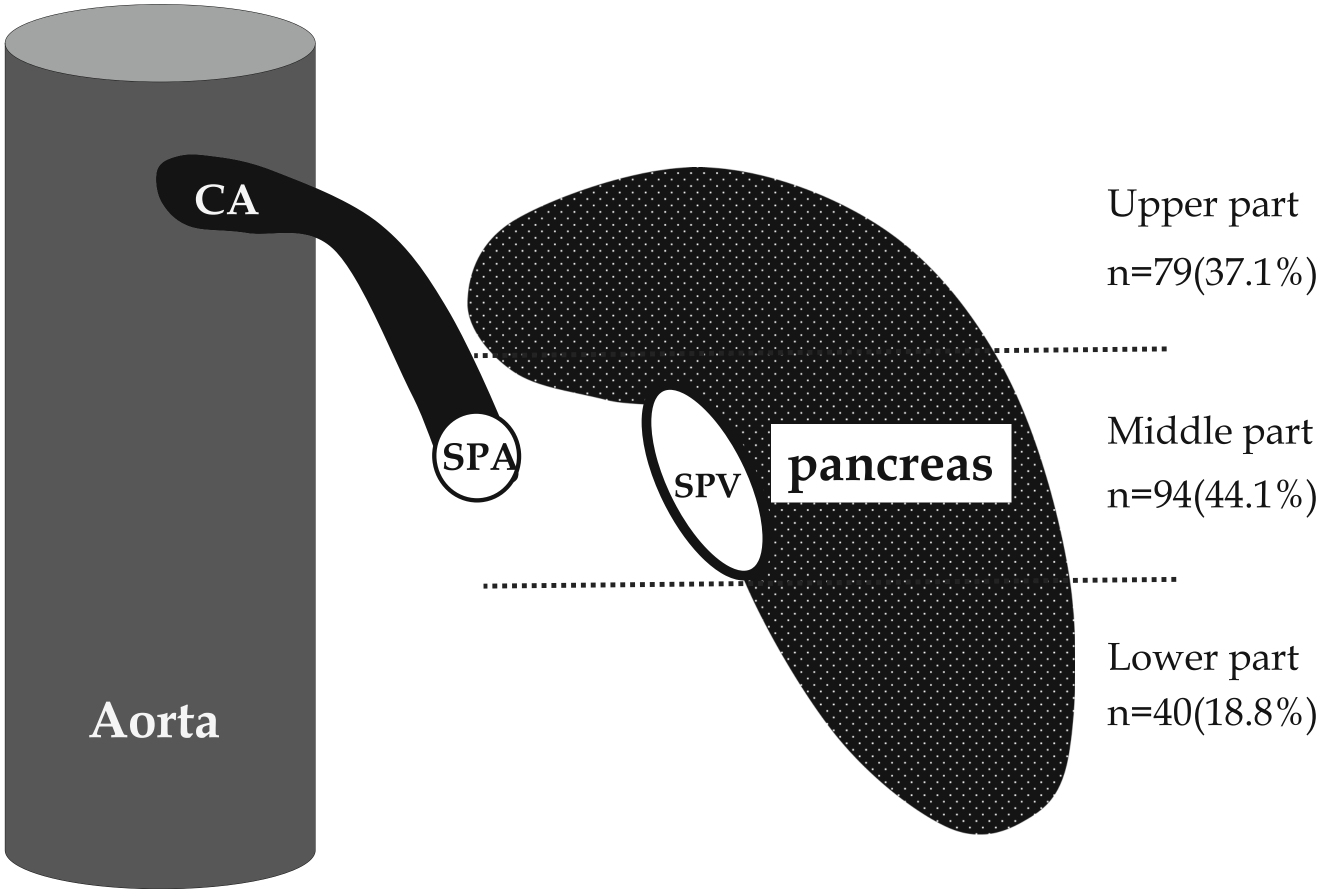


Fig. 4 The anatomic relationship of the SPA origin and the pancreas. SPA, splenic artery; SPV, splenic vein; CA, celiac axis

Table 1 Demographic and intraoperative characteristics

	Unmatched pairs			Matched pairs		
Variables	O-aRAMPS (*n*=33)	L-aRAMPS (*n*=30)	*p value*	O-aRAMPS (n=15)	L-aRAMPS (*n*=15)	*p value*
Gender (male/female)	13/20	17/13	0.9882	9/6	9/6	1.000
Age (yr), median (range)	71(52–86)	74(46–89)	0.211	76(55–86)	74(52–85)	0.781
BMI, median (range)	22.8(13.7–28.5)	22.3(16.2–28.7)	0.641	21.9(13.7–28.5)	22.3(17.1–27.9)	0.929
ASA score (1/2/3)	2/25/5	1/23/6	0.801	0/13/2	1/11/3	0.869
Diabetes mellitus (yes/no)	8/25	8/22	1.000	3/12	3/12	1.000
T stage at diagnosis (Tis/1/2/3/4)	2/7/7/17	5/3/11/11/	0.177	2/2/6/5	3/1/5/6	0.869
Tumor location at diagnosis						
Body/body–tail/tail	13/11/9	6/11/13	0.205	6/6/3	4/6/5	0.889
Diameter of the MPD (mm)	2.0(0.6–17.0)	1.7(0.8–11.0)	0.036	2.0(0.8–9.5)	1.6(0.8–1.1)	0.519
Operative procedure						
Anterior/posterior RAMPS	20/13	27/3	0.036	8/7	13/2	0.108
Operative time (min), median (range)	382(256–674)	389(280–576)	0.256	423(256–628)	393(280–463)	0.079
Blood loss (g), median (range)	215(30–1030)	18(0–180)	<0.001	220(40–1030)	30(0–100)	<0.001
Blood transfusion rate (%)	0	0		0	0	
Additional resection (yes/no)*	11/22	8/22	0.595	4/11	3/12	0.471

BMI body mass index. *ASA* the American Society of Anesthesiologist physical status classification. *MPD* main pancreatic duct

*including the gall bladder, liver, adrenal gland, stomach, small intestine, and colon

Table 2 Postoperative outcomes

Variables	Unmatched pairs			Matched pairs		
	O-aRAMPS (*n*=33)	L-aRAMPS (*n*=30)	*p value*	O-aRAMPS (*n*=15)	L-aRAMPS (*n*=15)	*p value*
Hospital stay (days), median (range)	16(8–96)	14(8–67)	0.107	16(8–96)	12(8–35)	0.049
Length of abdominal drainage (days), median (range)	5(3–81)	5(3–57)	0.692	5(3–81)	5(3–32)	0.585
Resumption of oral diet (day), median (range)	4(2–58)	5(3–49)	0.291	4(2–58)	6(4–16)	0.901
Postoperative mortality, n. (%)	0	0		0	0	
Reoperation rate	0	0		0	0	
Postoperative morbidity, n. (%)	6(18.2)	4(13.3)	0.735	5(33.3)	3(20.0)	0.682
Clavien–Dindo≧3a, n.(%)	2(6.1)	2(6.7)	1.000	1(6.67)	1(6.67)	1.000
Specific complications, n. (%)						
Pancreatic fistula						
No/grade A/B/C	26(78.8)/5(15.2)/2(6.1)/0(0)	23(76.7)/6(20)/1(3.3)/0(0)	0.466	11(73.3)/3(20)/1(6.7)/0(0)	12(80)/2(13.3)/1(6.7)/0(0)	0.885
Delayed gastric emptying						
No/grade A/B/C	28(84.9)/1(3)/2(6.1)/2(6.1)	29(96.7)/0 (0)/1(3.3)/0(0)	0.359	11(73.3)/1(6.7)/2(13.3)/1(6.7)	14(93.3)/1(6.7)/0(0)/0(0)	0.441
Surgical site infection	2(6.1)	1(3.3)	0.483	2(13.3)	0(0)	0.483
Intra-abdominal hemorrhage	0(0)	0(0)		0(0)	0(0)	
Others	1(2.9)	0(0)	1.000	1(6.7)	0(0)	1.000

Table 3 Tumor characteristics and pathological findings

Variables	Unmatched pairs			Matched pairs		
	O-aRAMPS (*n*=33)	L-aRAMPS (*n*=30)	*p value*	O-aRAMPS (*n*=15)	L-aRAMPS (*n*=15)	*p value*
Tumor size (mm), median (range)	20.4(3.5–40.7)	23.1(4.3–82.7)	0.152	30.1(1.3–40.7)	35.0(4.3–74.0)	0.907
TNM stage						
0/IA/IB/IIA/IIB/III/IV	2/3/1/4/20/3	6/2/1/4/9/0	0.187	2/2/0/2/7/2	2/1/3/4/5/0	0.681
Total number of LN dissected, median (range)	25(7–80)	18(5–51)	0.108	19(9–71)	22(8–37)	0.471
Dissected LN number around the SMA, median (range)	3(0–15)	3(0–15)	0.347	2(0–15)	5(0–13)	0.189
Total number of metastatic LNs, median (range)	1(0–21)	0(0–5)	0.037	1(0–4)	0(0–5)	0.564
Metastasis of individual LN stations, n.(%)[a]						
No. 7	1(3.0)	1(3.3)	0.815	0(0)	0(0)	
No. 8	1(3.0)	0(0)	0.399	0(0)	0(0)	
No. 9	1(3.0)	0(0)	0.399	0(0)	0(0)	
No. 10	0(0)	0(0)		0(0)	0(0)	
No. 11	17(51.5)	7(23.3)	0.093	8(61.5)	3(20.0)	0.123
No. 12	2(6.0)	0(0)	0.503	0(0)	0(0)	
No. 14	5(15.1)	1(3.3)	0.101	1(6.7)	1(6.7)	1.000
No. 16	3(9.0)	0(0)	0.254	0(0)	0(0)	
No. 18	2(5.7)	0(0)	0.513	0(0)	0(0)	
R0/1/2 resection, n. (%)	30(90.9)/3(9.1)/0(0)	29(96.7)/1(3.3)/0(0)	0.092	14(93.3)/1(6.7)/0(0)	15(100)/0(0)/0(0)	0.483
Adjuvant chemotherapy (yes/no)	28(84.8)/5(15.2)	20(66.7)/10(33.3)	0.139	12(80.0)/3(20.0)	11(73.3)/4(26.7)	1.000
Time until start Adjuvant chemotherapy(day), median (range)	36(9–120)	45(7–93)	0.624	36(9–120)	27(7–58)	0.194
Recurrence, n. (%)	13(39.4)	4(13.3)	0.025	5(33.3)	3(20.0)	0.682

[a] Numbers and names of LN stations: 7, along the left gastric artery; 8, along the common hepatic artery; 9, along the celiac axis; 10, at the splenic hilum; 11, along the splenic artery; 12, in the hepatoduodenal ligament; 14, along the SMA; 16, between the abdominal aorta and inferior vena cava; 18, along the inferior margin of the body to the tail of the pancreas. R0, microscopically curative resection; R1, microscopically positive resection margin; R2, macroscopically positive resection margin

artery-first approach is technically safe and feasible in patients with resectable pancreatic cancer.

The oncological principles of RAMPS with an artery-first approach for pancreatic cancer are as follows: (1) early judgment of R0 resection without any useless resection of organs or vessels before reaching the point of no return; (2) complete lymph node clearance around the body and tail of the pancreas, including around the SMA; and (3) modular setting of the plane of dissection behind the pancreas to obtain negative posterior margins before transecting the pancreas [15]. The pathological outcomes, including the R0 resection rate and the total number of lymph nodes harvested, were equivalent in both study groups according to a matched-pair analysis. The magnified laparoscopic view through the caudal side offered a safe lymphadenectomy around the major vessels, preparation around the SMA, and identification of the origin of the SPA before transecting the pancreas. As a result, oncological safety in terms of cancer-free margins (R0 resection), adequate lymphadenectomy, and secure dissection between the posterior aspect of the pancreas and the SMA was obtained in this study. Although L-aRAMPS is a surgical challenge in the management of pancreatic cancer, our results suggest that L-aRAMPS can satisfy these oncological principles in select patients. On the other hand, Sahakyan et al. [24] reported that extended LDP did not contribute to the favorable oncologic prognosis for patients with cancers of the body and tail of the pancreas. Furthermore, we empirically understand that open surgery is more suitable than laparoscopic procedure in borderline or locally advanced cases. These contradictory results may show the immaturity of minimally invasive surgery. We will need to discuss over time the true indication and limitation of minimally invasive LDP in pancreatic cancer management.

From a technical standpoint, exposure of the SMV at the inferior border of the neck of the pancreas secures the approach to the SMA because the SMA is close to the SMV at the left aspect of the SMV. A thin, soft, connective tissue containing lymph nodes is present between the SMV and SMA, and it can be dissected safely up to the origin of the SMA under a magnified view in the laparoscopic approach. Moreover, the dissection plane at the anterior border of the SMA finally leads to an appropriate plane around the origins

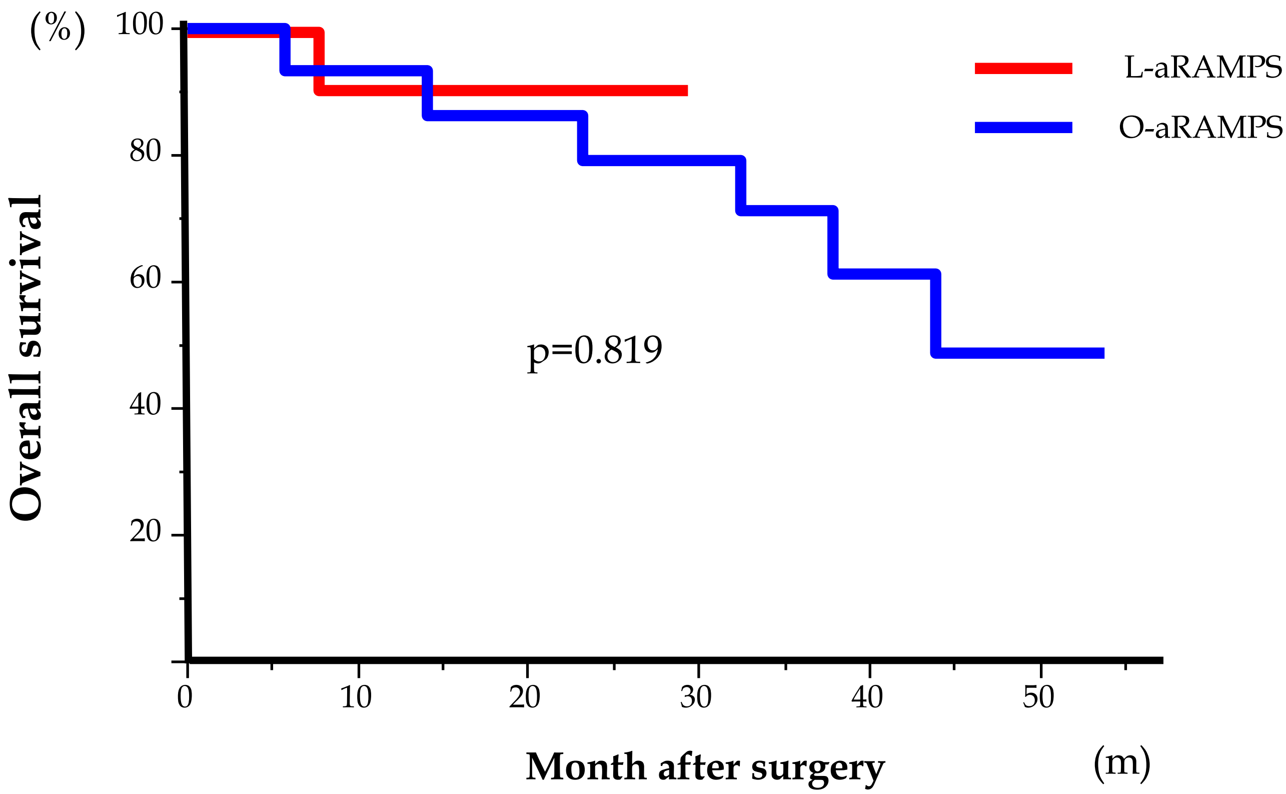


Fig. 5 Overall survival after open and laparoscopic radical antegrade modular pancreatosplenectomy with an artery-first approach using matched-pair analysis

of the SPA and common hepatic artery at the superior and posterior aspects of the pancreas. To secure the origin of the SPA in LDP, a caudal approach through the anterior aspect of the SMA is simpler, easier, and safer than an anterior approach though the upper border of the body because 68% of the SPA origin is located in middle and lower parts of the pancreas body, which are positioned deep behind the upper border of the pancreas. We think this is one of the biggest advantages of the artery-first approach in laparoscopic RAMPS. Furthermore, our procedure facilitates reliable lymphadenectomy around the hepatic artery and celiac trunk before transecting the pancreas because the posterior and superior aspects of the body of the pancreas have already been divided.

As far as we know, our report is the first comparison study between laparoscopic and open procedures in an artery-first approach for RAMPS using matched-pair analysis; yet, the present study has several limitations. First, potential patient selection bias could not be excluded because of the retrospective design. Second, given the small sample size and short follow-up time for observation, the study may be underpowered. Third, it was not possible to compare the L-aRAMPS group with laparoscopic RAMPS without the artery-first approach group, which limits the generalization of our findings. Fourth, we did not evaluate the patient's quality of life, which is an important endpoint in cancer management. More suitable patients for L-aRAMPS should be clarified with a long follow-up time in a large cohort study, and prospective randomized controlled trials should be conducted to confirm our preliminary findings.

Conclusion

L-aRAMPS is technically safe and oncologically feasible. To secure the SPA origin and achieve a sufficient lymphadenectomy around the major vessels with R0, a laparoscopic artery-first approach could be an advantageous surgical option for patients with resectable cancer in the body or tail of the pancreas.

Authors' contributions Study conception and design: Y Kawabata; Acquisition of the data: Y Kawabata, H Hayashi, S Kaji, Y Fujii, and K Nishi; Analysis and interpretation of the data: Y Kawabata and S Kaji; Drafting of the manuscript: Y Kawabata; Critical revision of the manuscript: Y Kawabata and Y Tajima.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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