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ORIGINAL ARTICLE

Conversion to open laparotomy during laparoscopic distal pancreatectomy: lessons from a single-center experience in 70 consecutive patients

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Abstract

Purpose The purpose of this study was to determine the factors influencing conversion from laparoscopic distal pancreatectomy (LDP) to open surgery, and the effect of such conversion on the outcome.

Methods This retrospective single-center study included 70 consecutive patients undergoing LDP. The primary endpoint was the rate of conversion to open surgery during LDP. The secondary endpoints were determining the reasons for conversion to open surgery, with detailed analyses of these cases and a comparison of the surgical outcome with and without conversion.

Results Seven patients (10%) required conversion to open surgery during LDP. Pancreatic ductal adenocarcinoma (PDAC) was identified as a risk factor for conversion ($p=0.010$). The reasons for conversion included technical difficulty (two bleeding, one severe adhesion) and pancreatic stump-related issues (two margin-positive, two stapling failures). Although the overall morbidity rate (29 vs. 11%, $p=0.48$) and the rate of clinically relevant postoperative pancreatic fistula (14 vs. 5%, $p=0.82$) were no different for the patients with or without open conversion, the postoperative hospital stay was significantly longer in the former (median 15 vs. 10 days, $p=0.03$).

Conclusions Careful preoperative assessment is required when planning LDP for PDAC. Although conversion to open surgery does not result in failure of LDP, efforts to reduce the duration of postoperative hospital stay and the occurrence of complications are desirable to improve the outcome of LDP.

Keywords Conversion to open surgery · Laparoscopic distal pancreatectomy · Laparoscopic pancreatectomy

Introduction

With the recent advances in laparoscopic techniques and accumulating surgical experience, laparoscopic distal pancreatectomy (LDP) is increasingly commonly performed and it may thus be regarded as a standard treatment for benign and malignant diseases of the left-side pancreas in selected patients. Numerous non-randomized control studies and several systematic reviews have documented significant reductions in intraoperative blood loss, the volume of blood transfusion required, complications, and hospital stay, relative to open distal pancreatectomy [1–6]. More recently, the first multicenter randomized controlled study found that compared with open distal pancreatectomy, minimally invasive distal pancreatectomy results in a reduced time to functional recovery [7]. However, despite the fact that most of these studies were performed only in high-volume specialized centers, high rates of conversion to open surgery of 16–31% were still reported [8–12]. This implies that LDP remains a technically challenging procedure, but there have been very few studies focused specifically on identifying the reasons for conversion to open surgery during LDP [10–12] and none has been reported on the patients requiring open conversion in detail. Thus, the purpose of the present study was to identify the factors associated with conversion to

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open surgery during LDP, and elucidate the clinical outcome in such patients.

Materials and methods

Patient and study design

This retrospective single-center study consisted of 70 consecutive patients undergoing LDP between June 2014 and January 2020. In our center, LDP was introduced for benign or low-grade malignant lesions of the pancreas in June 2014 and for malignant lesions in December 2016. LDPs were performed by an experienced surgeon who had previously treated > 40 cases by LDP. All demographic information, perioperative parameters, and outcomes were obtained from prospectively accumulated data. The primary endpoint was the rate of conversion to open laparotomy during LDP. The secondary endpoints included the factors associated with this, and detailed analyses of such patients relative to the surgical outcome in those without conversion to open surgery.

All patients provided their written informed consent before surgery according to the rules and regulations of our institution. This study was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Review Committee of Kindai University Faculty of Medicine (No. 31-093).

Surgical principles and procedures

For pancreatic ductal adenocarcinoma (PDAC), the indications for LDP were based on the Yonsei criteria [13] as follows: tumors had to be confined to the pancreas with an intact posterior pancreatic fascial layer, and at least 1 cm distant from the celiac artery. The exclusion criteria included tumor invasion to other organs except for the spleen, and to the portal vein. The presence of chronic pancreatitis, a history of severe acute pancreatitis, and previous upper abdominal major surgery were also exclusion criteria. D2 lymph node dissection was performed for malignant disease. LDPs were performed with or without splenectomy, the former for the following reasons: (1) presence of potential lymph node metastasis of the pancreatic neoplasm, and/or (2) technical difficulty in dissecting the distal pancreas from the splenic vessels as evaluated by preoperative imaging studies. Spleen-preserving LDPs were planned with the preservation of the splenic artery and vein. Spleen preservation while sacrificing the splenic vessels (Warshaw technique) was only performed when tumor dissection from the splenic vessels was found to be difficult intraoperatively. The details of the surgical procedures have been published elsewhere [3]. The transection line of the pancreas was determined using intraoperative ultrasonography. Pancreas transection was performed using a triple row stapler with bioabsorbable material (Endo GIA Reinforced Reload with Tri-Staple™ Technology, COVIDIEN, North Haven, CT, USA). The pancreas was slowly compressed with the stapler at the transection site over at least 10 min before transection.

Definition of postoperative complications

Postoperative complications were evaluated by means of a modified Clavien grading system [14]. Postoperative pancreatic fistula (POPF) was defined by the classification system of the International Study Group on Pancreatic Fistula (ISGPF) as an amylase level in the fluid collected on the third postoperative day (POD) > threefold the serum amylase level [15]. POPF was assigned to one of three categories, i.e., biochemical leak, grade B, or grade C according to the ISGPF clinical criteria. The amylase levels in drainage fluid on POD 3 were measured in all patients.

Statistical analysis

Categorical variables were presented as proportions, and continuous variables as a median and range. The significance of differences in the distributions of values was tested with the Shapiro–Wilk statistic. A comparison between the two groups was by the Mann–Whitney rank sum test. Proportions were compared using the Chi-square test, or Fisher's exact test when the expected values in any of the cells of the contingency table were below 5. All analyses were performed using the JMP 15.0 software program for Macintosh (SAS Institute, Inc, Cary, NC).

Results

Patient characteristics

The patient data are shown in Table 1, comprising 25 men and 45 women, median age 68, of whom 28 (40%) had malignant disease including PDAC ($n = 19$). Other diseases included neuroendocrine neoplasms ($n = 18$), intraductal papillary mucinous neoplasms ($n = 11$), mucinous neoplasms ($n = 7$), solid pseudopapillary neoplasms ($n = 4$), and others ($n = 12$).

Rate of conversion to open surgery and factors associated therewith

Seven patients (10%) required open laparotomy to be performed during LDP. We compared the rate of conversion to open surgery between the early period ($n = 35$) and late period ($n = 35$) of the study (Supplemental Table). There were no differences in the patient characteristics between

Table 1 Patient characteristics and an univariate analysis of the preoperative factors associated with conversion to open surgery

	Total (%) ($N=70$)	LDP completed ($N=63$)	LDP conversion ($N=7$)	p value
Sex				0.089
Male	25 (36)	20 (32)	5 (71)	
Female	45 (64)	43 (68)	2 (29)	
Age (years; median; range)	68 (18–89)	67 (18–89)	71 (52–82)	0.695
ASA score				0.378
I	20 (29)	19 (30)	1 (14)	
II	46 (66)	40 (63)	6 (86)	
III	4 (6)	4 (6)	0 (0)	
Body mass index (kg/m^2; median; range)	21.5 (15.0–31.5)	21.8 (15.0–31.5)	21.5 (18.6–25.1)	0.773
Diabetes				
No	49 (70)	45 (29)	4 (57)	0.447
Yes	21 (30)	18 (71)	3 (43)	
Previous abdominal surgery				0.394
No	50 (71)	46 (73)	4 (57)	
Yes	20 (29)	17 (27)	3 (43)	
Disease				0.010
No-PDAC	51 (73)	49 (78)	2 (29)	
PDAC	19 (27)	14 (22)	5 (71)	
Lesion size (mm; median; range)	23 (3–90)	23 (3–90)	25 (10–68)	0.395
Lesion site				0.088
Body	12 (17)	9 (14)	3 (43)	
Tail	58 (83)	54 (86)	4 (57)	
Diameter of the main pancreatic duct (mm; median; range)	2 (1–8)	2 (1–8)	1 (1–2)	0.333
Thickness of the pancreas (mm; median; range)	14 (7–31)	14 (7–31)	16 (10–23)	0.338

ASA American Society of Anesthesiologists, *PDAC* pancreatic ductal adenocarcinoma

the groups other than the nature of the disease (No-PDAC or PDAC). The rates of conversion to open surgery in the early and late periods were 9% and 11%, respectively (not significant). There were also no significant differences in duration of surgery, amount of blood loss, morbidity rate, or length of hospital stay between the groups. Table 1 shows a comparison between the patients where LDP could be completed and those requiring conversion to open surgery. According to a univariate analysis, PDAC was identified as a risk factor for the latter relative to other patients without PDAC ($p=0.010$). Five of the 19 patients (26%) with PDAC required conversion to open surgery during LDP.

Features of cases requiring conversion to open surgery and the reasons for conversion

A summary of the characteristics of the patients requiring conversion to open surgery is shown in Table 2. The reasons for conversion included technical difficulty-related issues ($n=3$) or problems related to the pancreatic stump ($n=4$). In

Table 2 Summary of the characteristics of patients requiring conversion to open surgery

Case	Age	Sex	Pathology	Reason for conversion	Detailed reason
1	61	F	PDAC	Technical difficulty-related	Bleeding from the splenorenal shunt
2	71	F	CP, Pseudocyst	Technical difficulty-related	Bleeding from the portal vein
3	54	M	NEN	Technical difficulty-related	Severe adhesion after left nephrectomy
4	76	M	PDAC	Pancreatic stump-related	Positive margin on the intraoperative frozen section
5	82	M	PDAC	Pancreatic stump-related	Positive margin on the intraoperative frozen section
6	80	M	PDAC	Pancreatic stump-related	Stapling failure
7	52	M	PDAC	Pancreatic stump-related	Stapling failure

PDAC pancreatic ductal adenocarcinoma, *CP* chronic pancreatitis, *NEN* neuroendocrine neoplasm

the former group, the reasons were related to the control of bleeding from the splenorenal shunt in one patient (Fig. 1), and from the portal vein in another patient with chronic pancreatitis (Fig. 2). The third patient had severe adhesions after left nephrectomy for renal carcinoma (Fig. 3). In the other group with pancreatic stump-related problems, there were two reasons for requiring conversion to open surgery. The first was the presence of a positive cancer margin at the pancreatic stump as determined by examining intraoperative frozen sections ($n=2$) (Fig. 4). The other was due to severe damage to the pancreatic parenchyma at the stapling site ($n=2$) (Fig. 5). For these 4 patients, additional pancreatic resections and our hand-sewn technique for stump closure [16, 17] were required and had to be performed via a small

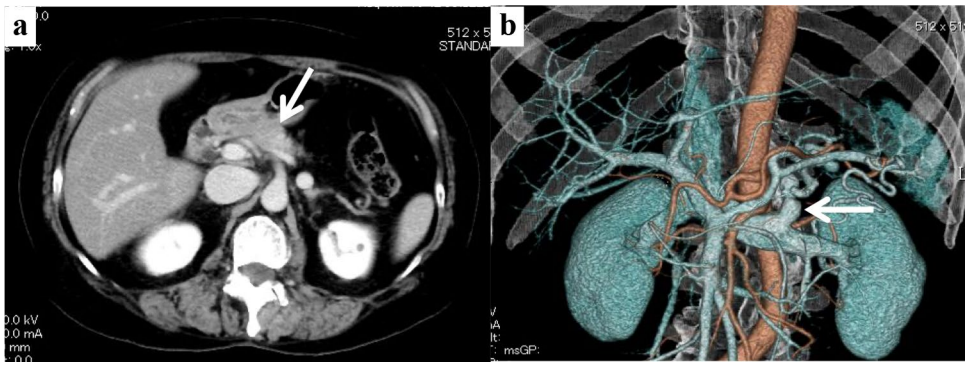

Fig. 1 Case 1: A 61-year-old female with pancreatic ductal adenocarcinoma required conversion to open surgery during laparoscopic distal pancreatectomy due to intraoperative bleeding from the splenorenal shunt. Preoperative multi-detector CT revealed a tumor in the body of the pancreas (arrow) (**a**). Three-dimensional image of the abdominal vessels revealed a splenorenal shunt (arrow) (**b**)

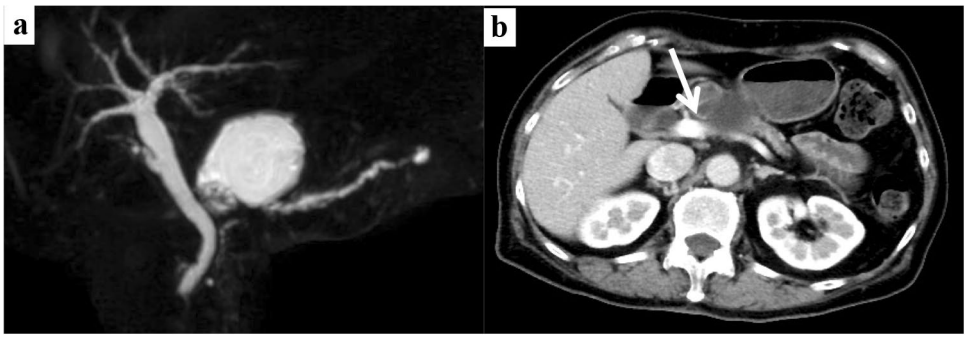

Fig. 2 Case 2: A 71-year-old female required conversion to open surgery due to intraoperative bleeding from the portal vein. MRCP revealed a cystic lesion with 5 cm in diameter (**a**). CT revealed that the lesion was in contacted with the portal and splenic veins (**b**). Preoperative diagnosis was branch-duct type of intraductal papillary mucinous neoplasm. However, the pathological diagnosis revealed a pseudocyst concomitant with chronic pancreatitis

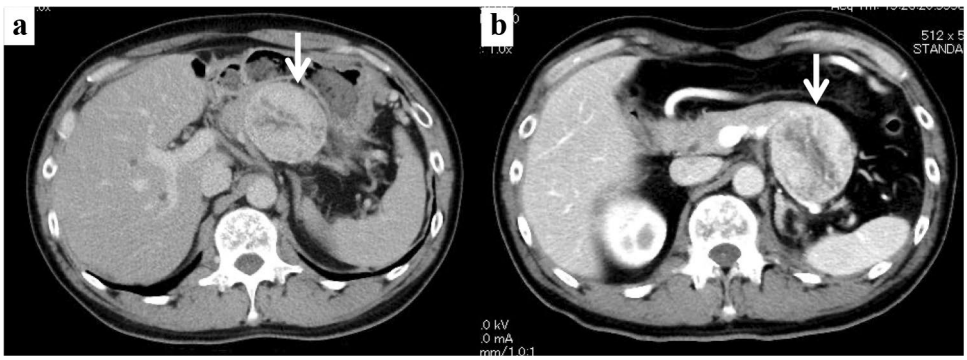

Fig. 3 Case 3: A 54-year-old man with a neuroendocrine neoplasm required conversion to open surgery due to severe adhesion after left nephrectomy. He was diagnosed with a neuroendocrine neoplasm (**a**) and left renal cancer simultaneously. He underwent laparoscopic distal pancreatectomy two months after retroperitoneoscopic nephrectomy. The location of the pancreatic tumor was moved to the back after nephrectomy (**b**)

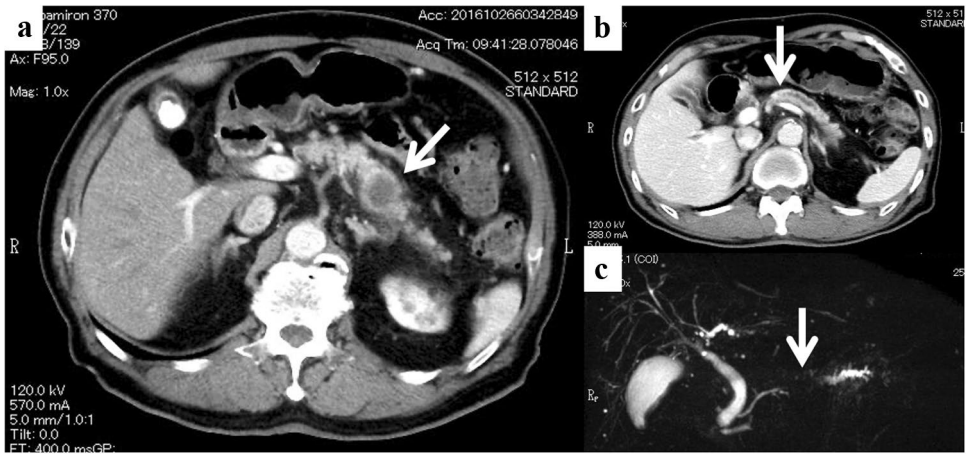

Fig. 4 Case 4: A 76-year-old man with pancreatic ductal adenocarcinoma required conversion to open surgery due to a positive cancer margin at the pancreatic stump as assessed by examining intraoperative frozen sections. CT showed a main tumor mass in the pancreatic tail (white arrow) (**a**). Case 5: An 82-year-old man with pancreatic ductal adenocarcinoma required conversion to open surgery due to positive cancer margin at the pancreatic stump as assessed by examining intraoperative frozen sections. CT showed no tumor mass, but dilation of the main pancreatic duct from the pancreatic body (white arrow) to tail (**b**). MRCP revealed that stenosis of the main pancreatic duct (white arrow) (**c**)

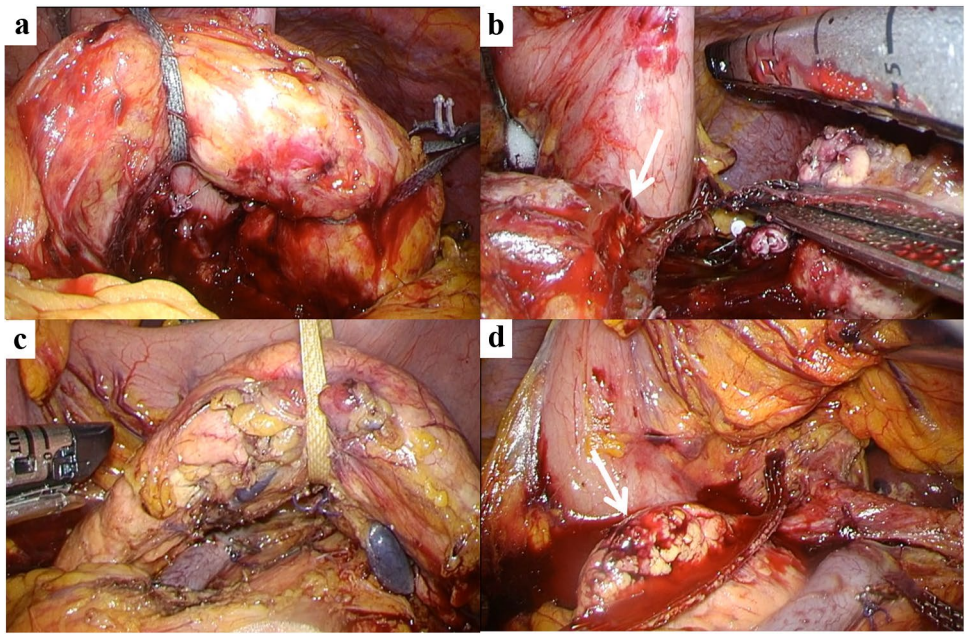

Fig. 5 Case 6: An 80-year-old man with pancreatic ductal adenocarcinoma required conversion to open surgery due to severe damage to the pancreatic parenchyma at the stapling site (white arrow) (**a**, **b**). Case 7: A 52-year-old man with pancreatic ductal adenocarcinoma required conversion to open surgery due to severe damage to the pancreatic parenchyma at the stapling site (white arrow) (**c**, **d**)

open laparotomy. The patients achieved R0 resection and none developed POPF.

Comparison of the operative data and postoperative outcomes in patients with or without conversion to open surgery

Table 3 shows the results of comparisons of the operative data and the postoperative outcomes in the two groups of patients. There were no significant differences between them regarding the type of resection planned (splenic resection or preservation), the type of resection performed, or the combined resection of other organs. The duration of surgery was significantly longer for patients requiring conversion to open laparotomy (a median of 353 min vs. 300 min for patients not converting to open surgery, $p = 0.016$). Blood loss was significantly greater in the former group (median of 700 ml vs. 50 ml, $p < 0.001$), and the proportion of patients requiring blood transfusion was higher (43% vs. 5%, $p = 0.011$).

Table 3 Operative data and postoperative outcomes

	LDP completion ($N=63$)	LDP conversion ($N=7$)	p value
Number of patients	63	7	
Type of resection planned			0.666
DP with splenectomy	43	6	
Spleen-preserving DP	20	1	
Type of resection performed			0.665
DP with splenectomy	45	6	
Spleen-preserving DP	18	1	
Combined resection of other organs			0.838
No	51	6	
Yes	12	1	
Operation time (minutes; median; range)	300 (166–582)	353 (320–551)	0.016
Blood loss (mL; median; range)	50 (5–1054)	700 (150–3202)	< 0.001
Blood transfusion			0.011
No	60	4	
Yes	3	3	
Mortality	0	0	1.000
Morbidity (Clavien–Dindo classification)			0.820
None or I	50	3	
II	6	2	
IIIa	5	2	
IIIb	2	0	
IV	0	0	
V	0	0	
Pancreatic fistula, ISGPF grade			0.985
None or BL	60	6	
B	3	1	
C	0	0	
Delayed gastric emptying	1	0	0.179
Intra-abdominal abscess	6	0	0.887
Postoperative hemorrhage	1	0	0.179
Wound infection	1	0	0.179
Portal thrombosis	1	1	0.191
Chylous ascites	1	1	0.191
Pancreatic pseudocyst	1	1	0.191
Other complications	3	1	0.350
Reoperation			0.473
No	61	7	
Yes	2	0	
Oral intake (POD; median; range)	4 (2–15)	4 (3–5)	0.113
Hospital stay (POD; median; range)	10 (5–113)	15 (12–23)	0.028
Readmission			0.275
No	61	6	
Yes	2	1	

LDP laparoscopic distal pancreatectomy, *DP* distal pancreatectomy, *ISGPF* the International Study Group of Pancreatic Fistula, *BL* biochemical leak, *POD* postoperative day

There was zero overall mortality in both groups, but the overall morbidity rate defined as ≥ grade II by the Clavien–Dindo classification tended to be higher in the patients requiring conversion to open surgery than in the other patients, but this difference did not reach statistical significance (57% vs. 21%, $p=0.267$). The frequency of patients with severe complications (grade IIIa and IIIb) also tended to be higher than in the patients completing LDP (29% vs.

11%, $p=0.475$), but there were no differences in the morbidity rates between the two groups. No patient in either group developed complications ≥ grade IV.

Regarding clinically relevant POPF as defined according to the ISGPF classification, one patient (14%) who required conversion to open surgery and 3 who did not (5%) developed POPF of grade B. None of the patients developed POPF grade C. Thus, there were no significant differences in the rate of occurrence of clinically relevant POPF between the two groups. There were also no significant differences in the development of other complications including delayed gastric emptying, intra-abdominal abscesses, postoperative hemorrhaging, wound infection, portal thrombosis, chylous ascites, or pancreatic pseudocysts. Furthermore, there were no significant differences in the rates of reoperation and readmission. Although there was no difference in the time to oral intake between the two groups, the length of postoperative hospital stay was significantly longer for patients requiring conversion to open surgery (median, 15 days vs. 10 days, $p=0.028$).

Discussion

The major findings of our study are, first, the frequency of patients requiring conversion to open surgery was 10% in 70 consecutive patients undergoing LDP; second, conversion to open surgery was significantly more frequent in patients with PDAC than in those with other indications; third, the reasons for conversion to open surgery were related to technical difficulty ($n=3$, 4%) and the pancreatic stump ($n=4$, 6%); fourth, although the overall morbidity and rates of clinically relevant postoperative pancreatic fistula (≥ grade B) were no different in these patients, the postoperative hospital stay was significantly longer in the patients converting to open surgery (median of 15 days vs. 10 days, $p=0.03$).

Several factors have been reported as reasons for conversion to open surgery during LDP, including the presence of excessive intra-abdominal and retroperitoneal fat, the extent of tumor invasion, the anatomy of vessels, and intraoperative bleeding [8, 9, 18]. However, few studies have identified the independent risk factors for conversion during LDP [10–12]. PDAC was identified as a risk factor for conversion to open surgery in the present study in which it was necessitated for 5 of 19 patients with PDAC (23%). This is consistent with a previous study by Daouadi et al. [8] who reported that PDAC was associated with a high conversion rate of 40%. Hua et al. [10] reported that malignant disease, multiorgan resection, and surgeons' case experience were all independent risk factors. Goh et al. [11] identified three factors comprising LDP with splenectomy, institutional experience, and individual surgeon case load having been < 5 cases. Casadei et al. [12] reported that the extent of the pancreatic resection (subtotal pancreatectomy) was the only independent factor. In a study by Lee et al. [9], the presence of visceral fat was an independent factor for conversion to open surgery. In two of these studies, the surgeons' experience was significantly associated with conversion. However, other identified factors were disparate in different studies. The surgeons' experience might affect these results because the education system and learning curves differ in each center. We evaluated the factors associated with conversion to open surgery during LDP in a setting not involving any learning phase, because all LDPs were conducted by an experienced surgeon. Therefore, the conversion rate in our study was relatively low compared to other studies.

The characteristics of cases requiring conversion to open surgery are summarized in Table 2. The reasons for conversion were related to technical difficulties including bleeding from the splenorenal shunt and the portal vein in patients with PDAC and chronic pancreatitis, respectively, and severe adhesions after left nephrectomy. Recently, Ohtsuka et al. [19] established a scoring system for such difficulties in LDP. They identified five factors including the type of operation, the pancreatic resection line, a tumor lying close to major vessels, tumor extension to peripancreatic tissue, and left-side portal hypertension and/or splenomegaly. According to this scale, our two patients requiring conversion to open surgery because of bleeding had high difficulty scores of 7 and 10. In general, a history of pancreatitis, previous surgery, and a large tumor size may influence the difficulty of laparoscopic pancreatectomy. Our patients also exhibited these factors.

Another reason for conversion to open surgery was pancreatic stump-related problems. Conversion was required due to severe damage of the pancreatic parenchyma at the stapling site ($n=2$), or positive margins at the pancreatic stump seen on intraoperative frozen sections ($n=2$). Of note, all 4 of these patients had PDAC. Positive margins of the transected pancreas as established by the intraoperative examination of frozen sections are sometimes encountered during pancreatectomy for PDAC even though careful pre- and intraoperative evaluations are performed. The rates of occurrence of positive margins have been reported to be between 11 and 21.7% [20–22]. Our results are in accordance with a previous study by Lee et al. [9] who described margin assessment and over-sewing of the pancreatic stump as well as other reasons for conversion to open surgery. Moreover, Casadei et al. [12] reported that extended pancreatic resection (subtotal pancreatectomy) was the only independent factor associated with conversion. LDP for PDAC is technically more challenging than LDP for benign and low-grade malignant disease with regard to en bloc resection, clear resection margins, and lymph node dissection. Our results indicate that pancreatic resection margins and stump management are likely important factors influencing

the requirement for conversion to open surgery when performing LDP for PDAC.

POPF remains the most common surgical complication after distal pancreatectomy. The pancreatic stump closure technique is one of the most important factors for preventing POPF. Stapler closure is a reliable and convenient method of stump closure during LDP. However, failure due to inadequate stapling with severe damage to the pancreatic parenchyma at the stapling site can occur, especially in thick and hard pancreases. Kawai et al. [23] reported the rate of severe stapling failure to be 2.9% in a prospective multicenter study that used the same type of stapler as was used in our study. As shown in Fig. 4, in our patients with stapler failure, the pancreas was thick and somewhat fibrotic. In our strategy, conversion to open surgery, but with small laparotomy, is always performed for adequate and secure stump management when an additional pancreatectomy is needed. This is due to the severe damage to the pancreatic parenchyma at the stapling site or positive margins of the pancreatic stump during LDP. We have developed a novel surgical technique using transpancreatic mattress sutures with Vicryl mesh (Polyglactin; Ethicon, Inc., Somerville, NJ, USA) around the stump to prevent POPF after open distal pancreatectomy; we have previously reported that its use is associated with the low rate of clinically relevant POPF of 5.6% [16, 17]. In fact, 6 of 7 patients who required conversion to open surgery underwent stump closure using this method, and none developed clinically relevant POPF. One patient did develop grade B POPF using a surgical stapler for pancreatic resection after conversion.

Our study is associated with several limitations. First, this was a single-center retrospective study with a relatively small sample size. Only 7 patients were included in the open conversion group. Second, although patient selection and the indications for LDP were decided in preoperative multidisciplinary meetings in our center, some selection biases may still have been present. Patients from two different cohorts were included in the present study. The first group, before December 2016, consisted only of benign and/or borderline malignant lesions, while the other included both these and malignant lesions. It is difficult to discuss fully the factors associated with conversion to open surgery during LDP and draw definitive conclusions due to the small number of cases and the heterogeneity of the patients in the present study. Therefore, a prospective multicenter large cohort study, focusing on high-risk cases such as PDAC, will be required to resolve this issue. Third, because this study was not undertaken during the learning phase of any involved surgeon, the results may not be representative of those of other centers with less experienced surgeons. However, as the learning curve was limited not only to one expert surgeon as well as assistant surgeons, with different theater staff and surgical instruments, we conducted a chronological comparison (early vs. late periods of the study) (Supplemental Table). As the results showed that the rates of conversion to open surgery as well as operation time, intraoperative blood loss, morbidity, and hospital stay were not significantly different, we concluded that any effect of the learning curve was small in our study. Recently, a multicenter prospective registration study on laparoscopic pancreatectomy in Japan has been reported [24]. According to that report, 1197 patients underwent LDP in 100 institutions in Japan with rates of completion of the planned operation of 92%. Postoperative complications (Clavien–Dindo classification ≥ grade III) occurred in 17% of these patients. Our results are therefore similar to these, with a rate of conversion to open surgery of 10% and postoperative complication rates (Clavien–Dindo classification ≥ grade III) of 13%.

In conclusion, PDAC was identified as a risk factor for the necessity of converting to open surgery during LDP; this was the case for 26% of such patients. There were two main reasons for this, namely, technical difficulties and stump-related issues. Our experiences suggest that a precise assessment of the preoperative diagnosis with careful attention paid to pancreatitis, previous surgery, and vessel anatomy (especially for portal hypertension or splenorenal shunts) is very important for avoiding the necessity for conversion to open surgery. Although conversion does not mean a failure of LDP, efforts for reducing the postoperative complications and longer hospital stays associated with conversion to open surgery are needed to improve the LDP outcomes.

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Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest to disclose.

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