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The treatment indication and optimal management of fluid collection after laparoscopic distal pancreatectomy

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Abstract

Background Recently, laparoscopic distal pancreatectomy (LDP) has become the standard procedure for resection of left-sided pancreatic tumors. Fluid collection (FC) at the resection margin of the pancreatic stump after LDP is a frequent radiological finding. However, there have been few treatment guidelines and the optimal management for this clinical finding is unclear. The aim of present study is to define the incidence of FC and suggest the optimal management for FC after LDP.

Methods A total of 1227 patients who underwent LDP between March 2005 and December 2015 were collected. FC was considered present when the longest diameter of the lesion on CT scan was >3 cm.

Results A follow-up with at least two CT image was available for 1102 patients. Of these, 689 (62.5%) patients showed initial fluid collection (IFC) at the pancreas resection site in immediate postoperative CT. IFC (+) group had higher proportion of men, BMI, and higher rate of concomitant splenectomy than IFC (−) group. Among patients with FC after LDP, the treatment group had more frequent leukocytosis and accompanying symptoms than the observation group. Seventy-seven patients underwent therapeutic interventions for FC after LDP. Among them, 55 (71.4%) patients underwent endoscopic ultrasonography-guided gastrocystostomy (EUS-GC). EUS-GC group had a higher success rate (85.6 vs. 63.6%, $p<0.033$) and shorter hospital stay after the intervention (5.2 vs. 13.3 days, $p<0.001$) than those who underwent other procedures.

Conclusions High BMI, male, and concomitant splenectomy contribute to the occurrence of FC after LDP. In most cases, FC after LDP resolved spontaneously over time with observation. The patients with symptomatic FC ultimately required treatment. EUS-GC is the optimal intervention therapy for FC after LDP.

Keywords Laparoscopic distal pancreatectomy · Fluid collection · Endoscopic ultrasonography · Symptom · Complication

Distal pancreatectomy (DP) is the surgical procedure of choice for benign and malignant left-sided pancreatic lesion. Minimally invasive surgery has revolutionized surgical approaches and currently is considered standard for DP [1].

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The benefits of laparoscopic distal pancreatectomy (LDP) over open DP include decreased pain, shorter hospital stay, faster outpatient recover, and higher spleen-preserving rate [2]. The most common postoperative complication after LDP is postoperative pancreatic fistula (POPF). There have been many studies of risk factors on the POPF and efforts to prevent and manage POPF after LDP [3–5]. Fluid collection (FC) at the resection margin of the pancreatic stump after LDP is another common radiological finding in follow-up computerized tomography (CT) scan. Although there are as many FC as POPF after LDP, the clinical impact of FC is not well known. Moreover, few recommendations exist about the optimal management of FC after LDP. The aim of this study is to evaluate the incidence, risk factors, and optimal treatment of FC after LDP based on a large volume single-center experience.

Materials and methods

Data of 1227 patients, who underwent LDP between March 2005 and December 2015 at Asan Medical Center, Seoul, Korea, were retrospectively analyzed using postoperative follow-up data until July 2017. We retrospectively reviewed the data for all patients who underwent LDP after approval by the Institutional Review Board. Among them, 1102 patients had at least 2 cross-sectional follow-up CT scans; the first follow-up CT at the immediate postoperative period (mean postoperative 4.21 days), and a consecutive CT at the outpatient clinic for routine follow-up (mean postoperative 114.64 days). This study was conducted on patients who had undergone postoperative CT scans more than 2 times for the analysis of the incidence and optimal management of FC after LDP.

The collected demographic data included age, sex, comorbidities, body mass index (BMI,kg/m^2), and American Society of Anesthesiologists score. Operative details included operative time (from incision to wound closure), estimated blood loss, and packed red blood cell transfusion obtained from the anesthesia record. The presence of a concomitant splenectomy or a multivisceral resection, or both, was recorded. Pathologic specimen details included final pathologic diagnosis and size of the largest tumor.

Surgery-related complications were graded according to the Clavien–Dindo system [6]. We divided the postoperative complications into in-hospital and late complication.

POPF was defined according to 2016 International Study Group of Pancreas Surgery consensus definitions [7]. Biochemical leakage was defined as drain output of any measurable volume of drain fluid on or after postoperative day (POD) 3, with an amylase content > 3 times the upper normal serum value. This condition applies to the original “grade A” POPF, and is no longer considered a true pancreatic fistula or an actual complication. Particular, a biochemical leakage implies no deviation in the normal postoperative pathway and, therefore, does not affect the normal postoperative duration of stay.

Definition

FC was defined as lesions ≥ 3 cm in longest diameter located around the pancreatic resection margin in CT images. Postoperative bleeding was not included in the definition of FC. Immediate fluid collection (IFC) was defined as FC in the first postoperative CT image. Delayed fluid collection (DFC) was defined as FC found in outpatient CT image with/without IFC. Of the 1227 patients who underwent LDP, 1102 had at least 2 cross-sectional follow-up CT images and were included in this study. Figure 1 shows the first flow chart of patient inclusion. The patients were divided into 2 groups according to the IFC status: IFC(+) and IFC(−) groups. Patients with IFC were then divided into 2 groups according to the management—observation and treatment groups. Figure 2 shows the second flow chart of patient inclusion. The patients were classified into 5 subgroups according to the change in FC: group 1—decreased IFC, group 2—no change in IFC, group 3—increased IFC, group 4—DFC without IFC, and group 5—no FC.

The interventions for FC after LDP included endoscopic ultrasound-guided gastrocystostomy (EUS-GC), percutaneous drainage (PCD) insertion, and endoscopic retrograde pancreatic drainage (ERPD) or endoscopic nasopancreatic drainage (ENPD). We analyzed the effectiveness of the different intervention types. Treatment success was defined as clinical improvement (resolution of fever, leukocytosis, pain, nausea, or vomiting) in addition to radiographic improvement or resolution of the FC without surgery or use of an alternative drainage technique.

Operative technique: LDP

LDP was performed through 4 ports (2 ports: 12 mm, 2 ports: 5 mm) with the patients in the supine position. The lesser sac was entered by dividing the gastrocolic ligament. Stomach was retracted upward with a stay suture placed in its posterior wall and pulled outside the abdomen using Endoclosure. Then spleen was mobilized from splenic flexure and proximal descending colon. Thereafter, tunneling under the pancreas was done by dissection on the inferior border of pancreas over superior mesenteric vein (SMV) till pancreas mobilized completely from SMV/portal vein. Then pancreas was encircled with umbilical tape to facilitate stapler insertion in pancreas transection line. Pancreas transection performed with linear stapler slowly over 3 min, to minimize parenchyma laceration and for good bleeding control. Dissection of lower border of pancreas from retroperitoneum was carried out from medial to lateral. Splenic artery was dissected from upper boarder of pancreas. Splenic artery and vein were encircled and divided between locking clips, in case of Warshaw operation or splenectomy. In Warshaw technique, left gastroepiploic and short gastric vessels were preserved; in Kimura procedure, all spleen blood supplies were preserved. If splenectomy was planned, the dissection continued up to the gastrosplenic ligament including the short gastric vessels, using harmonic scalpel and clips. Pancreas dissection from retroperitoneum continued until splenic hilum. Finally, spleen mobilized to finish the procedure. Patients with pancreatic ductal adenocarcinoma (PDAC) underwent laparoscopic distal pancreatectomy with splenectomy (LDPS) based on the concept of anterior or

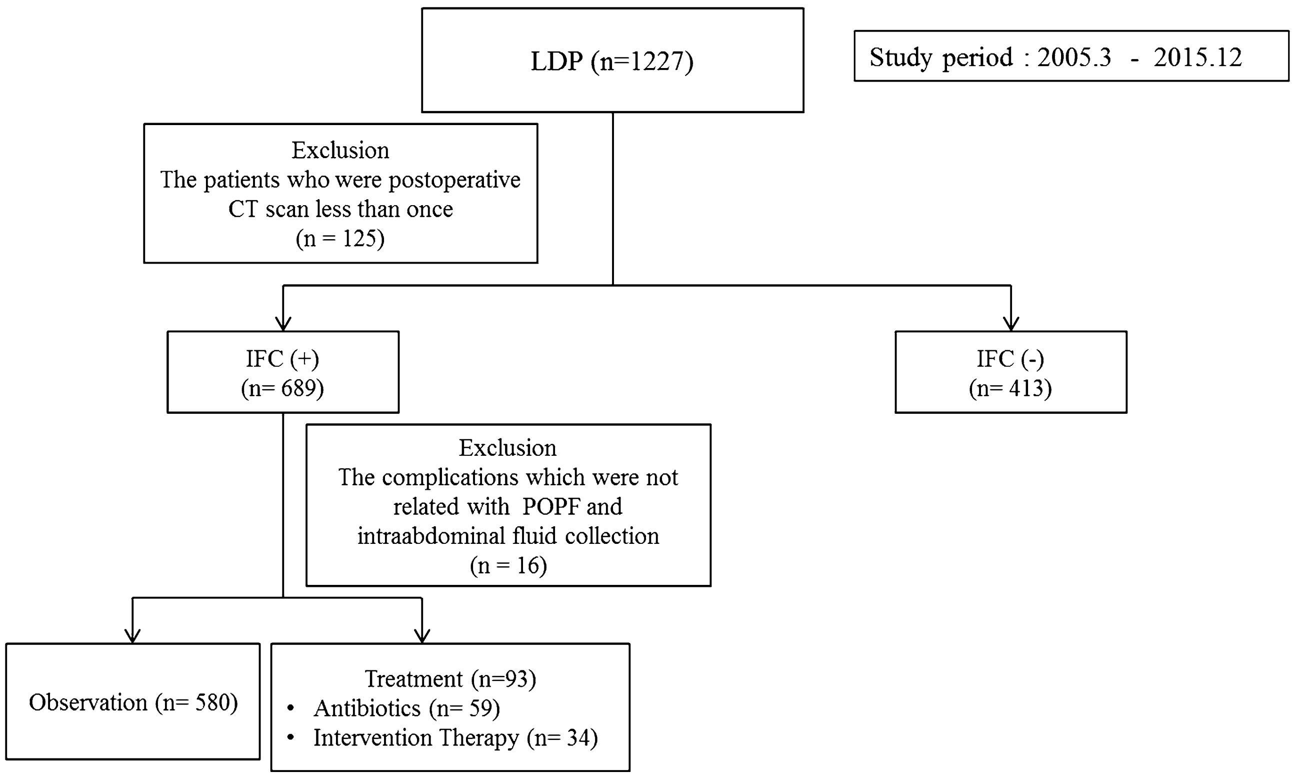

Fig. 1 Flow chart of patient inclusion. Patients were divided into 2 groups according to IFC status: IFC(+) and IFC(−) groups. Patients with IFC were then divided into two groups according to the management: observation and treatment groups. *LDP* laparoscopic distal pancreatectomy, *IFC* initial fluid collection, *POPF* postoperative pancreatic fistula

posterior radical antegrade modular pancreatosplenectomy (RAMPS), in which the peripancreatic retroperitoneal tissue (anterior RAMPS), along with the perinephric and adrenal (posterior RAMPS) tissue, is taken en bloc. As we had previously described [1, 8], to transect the pancreas safely in laparoscopic procedures, straight or rotated endoscopic linear staplers of various sizes (staple height, 3.5–4.2 mm) were used, depending on the thickness or hardness of the pancreas. At least one or more closed external drain was inserted for all patients.

Postoperative surveillance after LDP at Asan Medical Center

The routine postoperative management at our hospital after LDP is as follows. POD #1: sipping water, POD#2: eating soft diet, POD#3: CT follow-up and drain removal, and POD #5–7: total stitch out and discharge considered. At our center, a follow-up CT scan after LDP is routinely performed to evaluate patient status with regard to potential immediate postoperative complications on postoperative day 3. After discharge, follow-up CT scans are performed routinely to evaluate late complications and monitor for tumor recurrence regardless of IFC. Depending on the histopathological diagnosis, intervals of 3–6 months are commonly chosen for follow-up imaging (3 months for malignant disease; 6 months for benign disease).

Statistics

Categorical data were reported as number with percentage of the whole. Significance of categorical data was tested using a 2-tailed Fischer's exact test or Chi-square test. Continuous variables were expressed as mean and standard deviation (SD) or median and interquartile range (IQR). Significance of continuous data was tested using Student's *t* test to compare 2 means. $p < 0.05$ was used to determine significance. Statistical analyses were performed using SPSS 21.0 (IBM Corp., Armonk, NY, USA).

Result

Patient demographics and pathology

Collected data included patient demographics, operative variables, postoperative outcomes, pathologic findings, and postoperative follow-up details. Patients and tumor

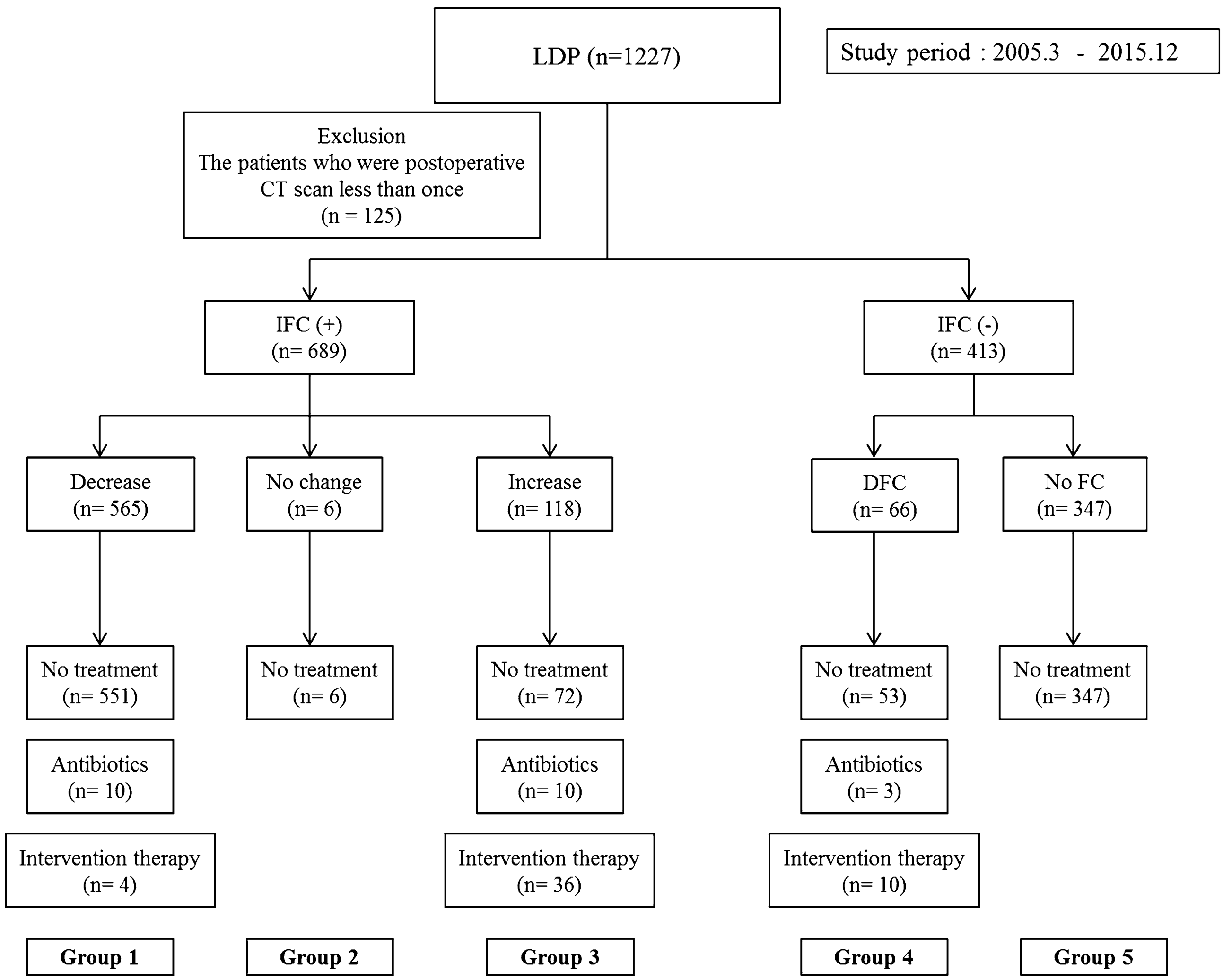

Fig. 2 Second flow chart of patient inclusion. Patients were classified into 5 subgroups according to the change in FC: group 1—decreased IFC, group 2—no change of IFC, group 3—increased IFC, group 4—DFC without IFC, group 5—no FC, *DFC* delayed fluid collection

characteristics for all 1102 patients (453 men, 649 women) are shown in Table 1. The median age at the time of operation was 54 (IQR 43–64) years. The median tumor size was 3 (IQR 2–4.5) cm. The most common indication for resection was an intraductal papillary mucinous neoplasm (IPMN, $n=231$, 21%), followed by pancreatic cancer in 204 (18.5%) patients and solid pseudopapillary neoplasm (SPN) in 173 (15.7%) patients.

Surgical technique and operative details

Of the 1102 patients who underwent LDP, 512 (46.5%) underwent spleen-preserving LDP (SP-LDP): 365 by main splenic vessel preservation and 147 supported by short gastric and gastroepiploic vessels (Warshaw technique). A total of 159 patients underwent LDP combined with other operations, including laparoscopic cholecystectomy, laparoscopic colectomy, laparoscopic wedge resection of the stomach, and laparoscopic resection of small bowel. The median operation time was 188 (IQR 152–233) min. The median length of postoperative hospital stay was 7 (IQR 6–10) days.

Postoperative complications

In-hospital complications were graded by the Clavien–Dindo classification (Table 2). The overall complication rate was 13.8%. Most patients experienced either no postoperative complications ($n=950$, 86.2%) or minor Clavien I/II events ($n=112$, 10.2%). Major morbidity (Clavien III/IV/V) occurred in 40 (3.6%). POPF was the most frequent complication, and 4.9% (54 cases) of the patients had clinically significant (grade B or C) fistulas. There was no 90-day mortality. Of the 1102 patients, 113 had surgery-related complications after discharge during

Table 1 Patient demographics and pathologic data

Variables		
Patients, *n*	1102	
Age, median (IQR), years	54 (43–64)	
Sex, female:male, *n*	649:453	
Body mass index (IQR), kg/m^2	23.6 (21.5–25.8)	
American Society of Anesthesiologists score, mean (SD)	1.8 (0.5)	
Tumor size, median(IQR), cm	3 (2–4.5)	
Diagnosis	**Number**	**%**
Pancreatic cancer	204	18.5
Intraductal papillary mucinous neoplasm	231	21
Pancreatic neuroendocrine neoplasms	123	11.2
Solid pseudopapillary neoplasm	173	15.7
Mucinous cyst neoplasm	162	14.7
Serous cyst neoplasm	124	11.3
Other pancreatic tumors or pancreatitis	85	7.7

IQR interquartile range; *SD* standard deviation

Table 2 Surgery-related complications of patients who underwent LDP

	$n=1102$	(%)
In-hospital complications by Clavien classification		
No	950	86.2
Grade I	5	0.5
Grade II	107	9.7
Grade III	40	3.6
Grade IIIa	34	3.1
Grade IIIb	6	0.5
2016 International Study Group Pancreatic Fistula		
No	617	56
Biochemical leakage	431	39.1
Grade B	54	4.9
Late complications by Clavien classification		
No	989	89.7
Grade II	55	5
Grade III	58	5.3
Grade IIIa	53	4.8
Grade IIIb	5	0.5

a median follow-up observation of 56.3 months. Of these, complications were classified as Clavien–Dindo grades II in 55 patients, grade IIIa in 53, and grade IIIb in 5. The most common late complication after LDP was complicated intra-abdominal FC with or without POPF.

Table 3 Comparison of demographics, operative, and pathologic findings between patients with(+) and without(−) immediate postoperative fluid collection after LDP

	IFC (+) ($n=689$)	IFC (−) ($n=413$)	*p* value
Age (years), mean ± SD	52.9 ± 13.4	53.2 ± 14.2	0.723
Sex (male), *n* (%)	303 (44)	150 (36.3)	0.012
BMI (kg/m^2), mean ± SD	24.3 ± 7.8	23.3 ± 3.4	0.013
ASA score, mean ± SD	1.82 ± 0.45	1.82 ± 0.48	0.965
Operative time, mean ± SD	201.3 ± 67.4	192.8 ± 61.9	0.036
Operation type			0.033
With splenectomy, *n* (%)	386 (56)	204 (49.4)	
Tumor size (mm), mean ± SD	36.5 ± 23.7	34.8 ± 20.9	0.229
Length of resected pancreas (cm), mean ± SD	9.1 ± 3.0	9.0 ± 3.3	0.561
Malignancy (cancer), *n* (%)	149 (21.6)	84 (20.3)	0.613

Comparative analyses

Figure 1 shows the first flow chart of patient inclusion. Patients were divided into 2 groups according to IFC status: IFC(+) and IFC(−) groups. Patients with IFC were then divided into 2 groups according to management: observation and treatment groups.

Demographic, operative, and pathologic findings of IFC(+) and IFC(−) groups after LDP

Table 3 shows the demographic, operative, and pathologic findings of all 1102 patients. Of these, 689 patients (62.5%) had IFC and 413 patients (37.5%) did not have IFC after LDP. Male sex was more predominant and BMI was higher in IFC(+) group than those of IFC(−) group. The IFC(+) group had a longer operation time (201.3 vs. 192.8, $p = 0.036$) and a higher rate of concomitant splenectomy (56 vs. 49.4%, $p = 0.033$) than the IFC(−) group.

Demographics, operative, pathologic, and laboratory findings of the observation and treatment groups in IFC(+) group after LDP

Of the 689 patients with IFC after LDP, we analyzed 673 patients for comparison of demographics, operative, pathologic, and laboratory findings between observation and treatment groups (excluded: 16 treated patients with complications unrelated to POPF and intra-abdominal FC) (Table 4). Among 673 patients with IFC, 580 (86.2%) did not need treatment but 93 (13.8%) required specific treatment. The FC size was larger, and the rate of concomitant splenectomy was higher in the treatment group for IFC after LDP. Serum C-reactive protein (CRP) level on POD 4 and drain amylase level on POD 1 and 3 were higher in the treatment group than in the observation group.

Figure 2 shows the second flow chart of patient inclusion. The patients were classified into 5 subgroups according to the change in FC as follows: group 1: decreased IFC, group 2: no change of IFC, group 3: increased IFC, group 4: DFC without IFC, and group 5: no FC.

Group 1: Of 689 patients with IFC, 565 had a size of decrease or spontaneous regression of IFC; however, 14 of them required specific treatment. Although the IFC size decreased, all patients who received treatment had recurrent abdominal pain, fever, and leukocytosis.

Group 3: We divided 118 patients with increased IFC into two groups: treatment and observation groups. We compared the 2 groups according to demographic, operative, pathologic, follow-up laboratory findings, and symptom status (Table 5). There were no differences in the initial and increased size of IFC between the 2 groups. However, the treatment group had higher level of serum white blood cell (WBC) count, CRP level, and proportion of patients with accompanying symptom than the observation group when they returned to the hospital.

Group 4: Of 413 patients without IFC, 66 had newly developed DFC on follow-up CT scans. We divided these 66 patients with DFC into two groups—treatment and observation groups. We compared the 2 groups according to the demographic, operative, pathologic, follow-up laboratory findings, and symptom status (Table 6). The treatment group had larger DFC size and more increased FC size than the observation group. The treatment group also had higher serum WBC count and proportion of patients with accompanying symptom than the observation group when they returned to the hospital.

Table 4 Comparison of demographics, operative, pathologic, and laboratory findings between observation and treatment groups for initial postoperative fluid collection after LDP

	Observation ($n = 580$)	Treatment ($n = 93$)	p value
Age (years), mean ± SD	52.6 ± 13.5	53.1 ± 13.2	0.762
Sex (male), n (%)	247 (42.6)	46 (49.5)	0.259
BMI (kg/m^2), mean ± SD	24.3 ± 13.5	24.1 ± 3	0.673
ASA score, mean ± SD	1.8 ± 0.48	1.8 ± 0.43	0.661
The size of initial fluid collection (cm), mean ± SD	5.0 ± 1.3	5.9 ± 1.8	< 0.001
Operation type			< 0.001
With splenectomy, n (%)	303 (52.2)	69 (73.2)	
Tumor size (mm), mean ± SD	36.5 ± 23.7	37 ± 24	0.411
Length of resected pancreas (cm), mean ± SD	9.0 ± 3.1	9.4 ± 3.0	0.25
Malignancy (cancer), n (%)	122 (20.7)	22 (23.7)	0.567
Serum WBC count, (10^3/mm^3), mean ± SD			
Postoperative 1 day	12,066 ± 7983	12,134 ± 7652	0.865
Serum CRP level, (mg/dL), mean ± SD			
Postoperative 1 day	5.0 ± 6.5	5.2 ± 5.8	0.634
Postoperative 4 day	10.3 ± 9.7	13.2 ± 10.8	< 0.001
Drain amylase (U/L), mean ± SD			
Postoperative 1 day	6621 ± 24,972	15,248 ± 45,316	0.008
Postoperative 3 day, mean ± SD	1822 ± 8918	14,192 ± 32,745	< 0.001

SD standard deviation; *BMI* body mass index; *ASA* American Society of Anesthesiologist; *WBC* white blood cell; *CRP* C-reactive protein

Table 5 Comparison of demographics, operative, pathologic, and laboratory findings between the observation and treatment groups for increased initial postoperative fluid collection

	Observation ($n=72$)	Treatment ($n=46$)	p value
Age (years), mean ± SD	53.3 ± 11.9	53.7 ± 12.3	0.874
Sex (male), n (%)	44 (61.1)	28 (60.9)	0.978
BMI (kg/m^2), mean ± SD	25 ± 3.3	24.6 ± 3	0.513
ASA score, mean ± SD	1.88 ± 0.37	1.85 ± 0.47	0.728
The size of initial fluid collection (mm), mean ± SD	52.6 ± 17.2	51 ± 15.1	0761
Increased size of initial fluid collection (mm), mean ± SD	21.2 ± 21.2	25.6 ± 22.3	0.289
Operation type			0.401
With splenectomy, n (%)	43 (59.7)	31 (67.4)	
Tumor size (mm), mean ± SD	33.3 ± 17.3	35.8 ± 20.4	0.411
Length of resected pancreas (cm), mean ± SD	8.8 ± 3.0	9.2 ± 2.8	0.57
Malignancy (cancer), n (%)	16 (22.2)	13 (28.2)	0.457
Serum WBC count, (10^3/mm^3), mean ± SD	8684 ± 4983	11,917 ± 6864	0.004
Serum CRP level, (mg/dL), mean ± SD	5.5 ± 6.8	9.3 ± 8	0.044
Accompanying symptom, n (%)	21 (29.2)	38 (82.6)	< 0.001
Postprandial discomfort	18	1	
Fever	0	3	
Abdominal pain	2	32	
Nausea or vomiting	1	2	

SD standard deviation; *BMI* body mass index; *ASA* American Society of Anesthesiologist; *WBC* white blood cell; *CRP* C-reactive protein

Table 6 Comparison of demographics, operative, pathologic, and laboratory findings between observation and treatment groups for delayed fluid collection

	Observation ($n=53$)	Treatment ($n=13$)	p value
Age (years), mean ± SD	54.7 ± 14.2	54.7 ± 12.2	0.994
Sex (male), n (%)	23 (43.4)	7 (53.8)	0.498
BMI (kg/m^2), mean ± SD	24.3 ± 2.9	24.4 ± 3.1	0.950
ASA score, mean ± SD	1.75 ± 0.48	1.77 ± 0.44	0.921
The size of delayed fluid collection (mm), mean ± SD	47.3 ± 9.6	67.1 ± 21.4	< 0.001
The increased size of initial fluid collection (mm), mean ± SD	28.6 ± 9.9	49.7 ± 18.5	< 0.001
Operation type			0.955
With splenectomy, n (%)	29 (54.7)	7 (53.8)	
Tumor size (mm), mean ± SD	33.9 ± 18.6	37.4 ± 21.2	0.571
Length of resected pancreas (cm), mean ± SD	8.5 ± 2.7	9.7 ± 3.2	0.57
Malignancy (cancer), n (%)	10 (18.9)	1 (7.7)	0.333
Serum WBC count, (10^3/mm^3), mean ± SD	6558 ± 1905	12,176 ± 7273	< 0.001
Accompanied symptom, n (%)	3 (5.9)	11 (84.6)	< 0.001
Postprandial discomfort	2	0	
Fever	0	0	
Abdominal pain	1	8	
Nausea or vomiting	0	3	

SD standard deviation; *BMI* body mass index; *ASA* American Society of Anesthesiologist; *WBC* white blood cell; *CRP* C-reactive protein

Therapeutic interventions for FC after LDP

Seventy-seven patients (47 men, 30 women; mean age, 54 years) underwent therapeutic interventions of FC after LDP for a median follow-up time of 56.3 months. EUS-GC was performed in 55 patients. Figure 3 shows the EUS-GC procedure at our center. It was successful in 47 (85.5%) patients. However, 8 (14.5%) patients required

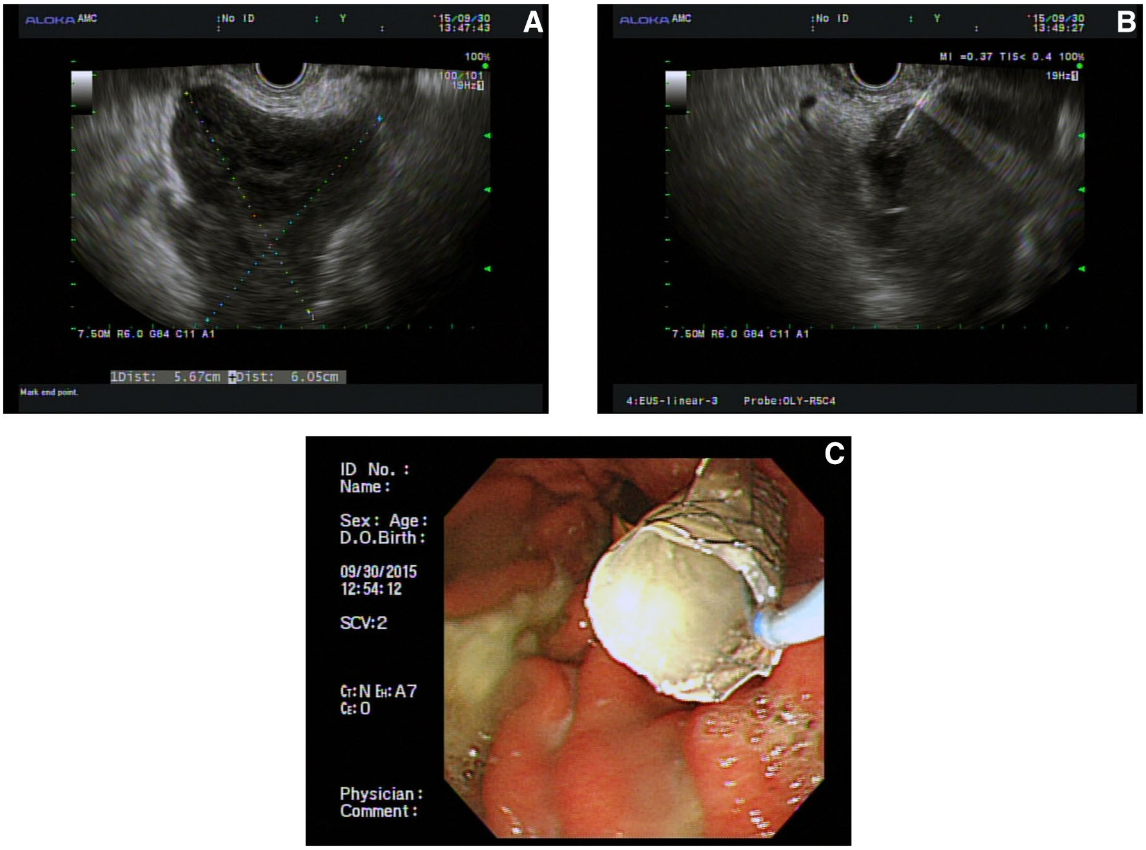

Fig. 3 Endoscopic ultrasound (EUS)-guided gastrocystostomy: **A, B** fluid collection at the stump of pancreatic resection after laparoscopic distal pancreatectomy was punctured under EUS guidance and **C** a full-covered self-expandable metal stent was placed across the gastrocystostomy tract. A large amount of dark-colored fluid gushed out through the full-covered self-expandable metal stent

repeat-procedures after the first EUS-GC. Six patients had stent malfunction, one patient had persistent pain after EUS-GC, and one patient had recurrence of FC after the removal of the first stent. No procedure-related complications were encountered. Thirteen patients had PCD insertion for FC after LDP. It was successful in 10 (76.9%) patients. Three patients required repeat-procedures. Two patients had additional EUS-GC because of persistent pancreatic leakage. One patient required additional PCD insertion owing to FC recurrence after removal of the first PCD. ERPD (or ENPD) was performed to 9 patients with FC after LDP. The first ERPD for FC failed in 5 (55.6%) patients. One patient required embolization with angiography and was transferred to intensive care unit because of bleeding after ERPD. In 2 patients ERPD was replaced owing to malfunction, and two patients had additional EUS-GC because of persistent pancreatic leakage. We compared the efficacy for management of FC after LDP between EUS-GC and other procedure groups (Table 7). EUS-GC group had a higher success rate (85.6 vs. 63.6%, $p<0.033$) and shorter hospital stay after

Table 7 Comparison of the therapeutic effects for management of FC after LDP of EUS-GC and other procedures

	EUS-GC ($n=55$)	Other procedures ($n=22$)	p value
Sex (male), n (%)	31 (56.4)	16 (72.7)	0.183
BMI (kg/m^2), mean ± SD	23.9 ± 3.0	24.8 ± 2.9	0.296
Success rate, n (%)	47 (85.6)	14 (63.6)	0.033
Procedure-related complication, n (%)	0	1 (4.5%)	0.111
Hospital stay after intervention, (days), mean ± SD	5.2 ± 4.5	13.3 ± 15.1	0.001

EUS-GC endoscopic ultrasound-guided gastrocystostomy; *BMI* body mass index; *SD* standard deviation intervention (5.2 vs. 13.3 days, $p < 0.001$) than the other procedure groups.

Discussion

Since the first series of LDP in 1996 [9], multiple studies have demonstrated the safety and benefits of laparoscopic pancreatic surgery [1, 10–13]. LDP is gaining popularity and is considered by some as the standard approach to DP for left-sided pancreatic tumors. With the operation being more widely performed, more effort has been made to treat its complications. Most of the previous studies were about the prediction, treatment, and prevention of POPF [5, 14, 15]. However, little is known about the FC after LDP which is a common finding. POPF and FC do not always accompany each other. POPF can occur without FC and vice versa. Several reports evaluating POPF have shown that drain amylase data can be inaccurate. If drains are not placed at the pancreatectomy site, it is not possible to measure drain amylase accurately. Moskovic et al. reported that drain amylase is not a sensitive or specific predictor of which patients will develop clinically significant POPF after pancreas resection [16]. By contrast, FC measured using routine CT is more accurate. Our study focused on FC findings regardless of the presence or absence of POPF. Most FCs were temporary and without symptoms, but some FCs were clinically significant. Therefore, it is important for postoperative care to distinguish between them and treat them accordingly. Sierzega et al. [17] reported that one-fourth of patients developed various types of FC after pancreatic surgery. Around half of the cases were asymptomatic and spontaneously resolved. Tjaden et al. [18] presented FC occurred at 43% of DP. In the present study, there were 755 (68.5%) patients whose FC was identified more than once on CT scans during a median follow-up time of 56.3 months. This discrepancy in the incidence rate of FC seems to be due to the different definitions of FC and different follow-up durations. In the present study, FC was defined as lesions ≥ 3 cm in longest diameter located around the pancreatic resection margin on CT images. At our center, follow-up CT scan after LDP is routinely carried out to evaluate the patients' status with regard to potential immediate postoperative complications POD 3. We also perform CT scan to evaluate late complications as well as surveillance for recurrence of tumors in the outpatient clinic with intervals of 3–6 months. Of the 1227 patients who underwent LDP, 1102 patients with 2 cross-sectional follow-up CT were analyzed. The development of FC at pancreatic stump is a frequent complication after LDP. In this study, 62.5% (689/1102) of patients had IFC after LDP. The IFC(+) group had a higher proportion of male patients and higher BMI. It was well known that high BMI is the risk factor of postoperative complications and that the amount of intra-abdominal visceral adipose tissue is higher in male than in female patients [19, 20]. Many surgeons feel that visceral adipose tissue levels should be considered as an important risk factor for postoperative complications. Furthermore, increasing BMI correlated with total pancreatic fat. Therefore, it seems that increasing BMI may lead to greater amounts of fatty infiltration of the pancreas, a soft gland, and an increased risk to FC related with pancreatic fistula. In the present results, concomitant splenectomy was associated with a higher rate of FC after LDP. There were studies showing higher complication rates including pancreatic fistula after DP with concomitant splenectomy. There has been hypothesis that potential devascularization of the pancreatic remnant in splenic preservation causes failure of wound healing process in the pancreatic stump to fail [21–23].

Most patients with IFC had no symptom and observation without treatment was possible. After excluding 16 treated patients with complications unrelated to POPF and IFC, we analyzed 673 patients for comparison of demographics, operative, pathologic, and laboratory findings between the observation and treatment groups. Among 673 patients with IFC after LDP, 580 (86.2%) did not need treatment but 93 (13.8%) required specific treatment. All patients who needed treatment in the IFC(+) groups had symptoms, such as abdominal pain, indigestion, and fever, and higher serum WBC or CRP. The IFC size was larger (5.9 vs. 5 cm, $p < 0.001$), and serum CRP and drain amylase level were higher in the treatment group than in the observation group. The specific treatment for symptomatic IFC should be considered for large-sized FC with inflammatory laboratory findings. Most cases of IFC (80.8%, 557/689) showed spontaneous resolution in follow-up CT scans and remained asymptomatic. Of the patients with increased IFC size, 39% (46/118) needed additional treatment owing to aggravated IFC with accompanying symptoms, leukocytosis, and fever. Although the FC size was larger (mean = 52.6 mm) than the size of IFC in 72 patients (61%), these patients did not need treatment because they had no symptoms and abnormal laboratory findings. Of 413 patients without IFC, 66 had newly developed DFC on follow-up CT scans. Most of them (80%, 53/66) did not have specific symptoms related with DFC and did not need specific treatment. However, patients with large size of FC itself (mean size of FC = 67.1 mm) and rapid increase in FC size (mean size increase = 49.7 mm) with accompanying symptom and inflammatory signs needed treatment.

As most FC remained asymptomatic or resolved over time, treatment was frequently unnecessary. Of 755 patients whose FC was identified more than once on CT, the spontaneous resolution of FC was observed in 79.7% (602/755) and 153 (20.3%) received treatment during a median follow-up of 56.3 months. Only 10.2% of patients needed intervention therapy and 10.1% required antibiotics for FC after LDP. In our opinion, FC is not an absolute indication for treatment. Accompanying symptoms and inflammatory signs in blood test are more important to determining whether treatment is needed. One of the most important considerations when managing patients with FC is deciding if and when to provide intervention therapy. In the present study, all patients with intervention had symptoms with elevated of serum WBC count and CRP level. With persistent symptoms and infectious sign, a rapid increase in FC size is the determining factor for intervention therapy. The mean FC size in patients with intervention therapy was 7.7 cm, which was larger than that in patients with antibiotic therapy for FC (7.7 vs. 5.9 cm, $p < 0.001$). Intervention treatments, such as EUS-GC and PCD insertion, are invasive procedures and can lead to procedure-induced complications. Therefore, the decision to intervene or not must be made carefully. Although it is hard to establish a definite indication for an intervention, we considered that patients with symptoms (abdominal pain and fever) and abnormal laboratory findings (high serum CRP or serum WBC) needed further interventions. Size alone was not a unique descriptor of the indication for the intervention of FC. However, the patients with relatively large FC (≥ 8 cm) and rapid growing FC (≥ 2 cm/month) were more likely to require intervention. Although EUS-GC was introduced relatively recently, it is now being implemented more often because of its greater success rate and less inconvenience than conventional PCD or ERCP. Therefore, EUS-GC has emerged as the optimal management for FC after DP [24–26]. In the present study, EUS-GC was found to be a highly effective intervention for FC after LDP. As our experience grew, we mainly performed EUS-GC because of the shorter hospital stay after the intervention, lower rate of procedure-related complication, and higher success rate. Moreover, because there is no externally inserted drainage, it could improve the patient's quality of life during treatment.

Conclusion

High BMI, male sex, and concomitant splenectomy contribute to the occurrence of FC after LDP. In most cases, FC after LDP resolved spontaneously over time with observation only. Patients with symptomatic FC ultimately required treatment. Intervention is truly only required for a minority of patients with rapidly growing symptomatic FC, and EUS-GC is the standard procedure for intervention of FC after LDP.

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Compliance with ethical standards

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