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ORIGINAL ARTICLE

# Pancreatic fistula following laparoscopic distal pancreatectomy is probably unrelated to the stapler size but to the drainage modality and significantly decreased with a small suction drain

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## Abstract

**Introduction** Risk factors of postoperative pancreatic fistula (POPF) after laparoscopic distal pancreatectomy (LDP) are not well known and were studied, including the stapler cartridge size and drainage modality.

**Methods** Between January 2008 and December 2016, 181 LDP were performed and the pancreas was sectioned by stapler in 130 patients (72%). Patients received white (2.5 mm), blue (3.5 mm), or green (4.1 mm) staplers and the size was not based on any pre or peroperative randomization. As primary analysis of the first 84 patients (28 in each group) showed no effect of stapler size on POPF, we decided to use the white (total = 47) or blue and finally the blue (total = 55) of medium size for standardization. Drainage was obtained by multi-tubular drain (first, 79) and a small suction drain (last, 102). Risk factors of POPF were studied and grades B and C were compared to grade A or no POPF.

**Results** POPF ($n = 66$; 36%) was of grade A ($n = 25$, 14%), grade B ($n = 32$, 18%), and grade C ($n = 9$, 5%). The comparison of the three groups of staplers showed that the blue stapler was used more with a small suction drain (85 vs 23%, $p < 0.0001$), had lower rate of grade B POPF ($p = 0.028$), and a shorter hospital stay ($p = 0.004$). On multivariate analysis, only the use of a small suction drain was associated with significant decrease in grades B and C POPF (6 vs 44%, odds ratio 7.385 (1.919–28.418); $p = 0.004$).

**Conclusion** The occurrence of POPF following LDP is influenced by the type of drainage alone and is significantly decreased with a small suction drain.

**Keywords** Laparoscopic approach · Minimally invasive approach · Pancreas · Surgery · Resection · Pancreatic fistula · Modality of drainage · Stapler size cartridge

## Introduction

Laparoscopic distal pancreatectomy (LDP) is more frequently used because dissection is performed distant from the main vascular structures, pancreatic anastomosis is not needed, and the vessels and the pancreas can be controlled by stapler with no need for ligation. Results of several retrospective comparative studies and meta-analyses have shown shorter hospital stays and fewer overall complications but no decrease in pancreatic-specific complications in LDP compared to open distal pancreatectomy (ODP) (3–8). In a recent Dutch randomized comparative study, LDP ($n = 51$) compared to ODP ($n = 57$) showed higher rate of clinically relevant postoperative pancreatic fistula (POFP) (39 vs 23%, $p = 0.07$) but shorter hospital stay (4 vs 6 days, $p < 0.001$) (9). Although LDP is mainly performed for low potential malignant

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diseases, many retrospective comparative studies have confirmed that it is safe for resection of adenocarcinoma (1, 2), making it a viable and valid alternative to ODP. In a recent propensity score-matched analysis for pancreatic adenocarcinoma, LDP ($n = 563$) compared to ODP ($n = 563$) showed a similar 3-year overall survival (42 vs 36%, $p = 0.45$) with shorter hospital stay (6 vs 7 days, $p < 0.001$) (10). POPF is still the main complication of both approaches and is observed in 30–50% of cases, leading to other severe complications such as intra-abdominal abscesses, delayed gastric emptying, bleeding, wound infection, and sepsis. These complications limit the benefit of minimally invasive surgery and negatively influence the length of hospital stay and overall costs (11, 12). The incidence of POPF may be higher with LPD because the main factors that decrease the risk of POPF with ODP, such as elective main pancreatic duct ligation and section on the neck (13, 14), are not frequently performed with LDP. Although risk factors for POPF have been extensively studied with ODP, data with the LDP are limited. The aim of this study was to evaluate the risk factors of POPF with LDP in a particular stapler cartridge size and the type of drainage.

## Materials and methods

Between July 2008 and December 2016, all consecutive patients who underwent LDP were included. LDP was decided according to the surgeon's experience in laparoscopic surgery and relative contraindications included vascular invasion, acute or chronic pancreatitis, segmental portal hypertension, larges tumors, and adjacent organ resection. Malignant diseases (adenocarcinomas, neuroendocrine tumors (NET) > 2 cm, invasive intraductal papillary and mucinous neoplasia (IPMN), cystic and solid pseudo-papillary neoplasms, and other primary or secondary malignant pancreatic diseases) were treated by standard pancreatic resection but parenchymal sparing resections were performed in patients with low potential malignant diseases. All data were recorded prospectively.

### Surgical technique

The patient was installed in a supine position under general anesthesia with the legs spread apart and the monitor to the left. The surgeon was to the right of the patient, the assistant was between the patient's legs, and the nurse was to the right of the surgeon (Fig. 1a). Open coelioscopy was performed through the umbilicus and five trocars were inserted to prevent the surgeon and the assistant from crossing hands. A 30° optic, a Harmonic® shears (Ethicon, Issy les Moulineaux, France) and more recently a Thunderbeat seal and cut® (Olympus), and a bipolar cautery coagulation device were needed. The specimen was removed in all cases in a surgical bag through a trocar incision, a previous abdominal scar, or a suprapubic incision. An abdominal drain was routinely left in the surgical field.

### Splenopancreatectomy and variations

The gastrocolic ligament was divided, and short gastrosplenic vessels section was not performed before the splenic vessels had been controlled to limit inadvertent bleeding. The anterior surface of the pancreas was freed and the stomach was retracted by a gastric hanging maneuver developed by our team (15) (Fig. 1b). The inferior pancreatic border was freed and the mesentericoportal vein was identified. The superior pancreatic border was freed for identification and lymphadenectomy was performed along the celiac trunk branches. In all cases, the pancreas was divided before controlling the splenic vessels. Once these structures had been clearly identified, and as explained later, the pancreas was sectioned with or without the stapler. Mainly, the splenic vessels were stapled; the splenic vein was controlled first to simplify that of the splenic artery. The specimen was mobilized from right to left and the short and posterior gastric vessels were treated during this step. During mobilization, particular care was taken to avoid injury to the left colonic angle and the stomach. Freeing the spleen from the posterior peritoneal attachments can be difficult and in some obese patients, a hand-assisted approach was used. For radical splenopancreatectomy, dissection and lymphadenectomy was performed along the left border of the celiac trunk and the superior mesenteric artery and extended to expose the left renal vein with or without the adrenal gland.

### Distal/short pancreatectomy without splenectomy

LDP may be performed with or without preservation of the splenic vessels and short pancreatectomy including removal of 5–6 cm of the pancreatic tail. The shorts vessels were preserved in all cases and the first steps are similar to splenopancreatectomy. For LDP with splenic vessel preservation, the pancreatic gland was freed from all peritoneal attachments to facilitate dissection, the pancreas was then sectioned and dissection was performed from right to left. Dissection could be performed from left to right in patients with a short tail. Small vascular collaterals were controlled by an energy-based device, ligation, or clips. In LDP without splenic vessel preservation (Warshaw's technique) (16), the collateral circulation in the hilum was preserved as much as possible to minimize the risk of splenic infarction.

### Section of the pancreas

The level of pancreatic section depends on the indication. We always try to section the pancreas by stapler (Echelon

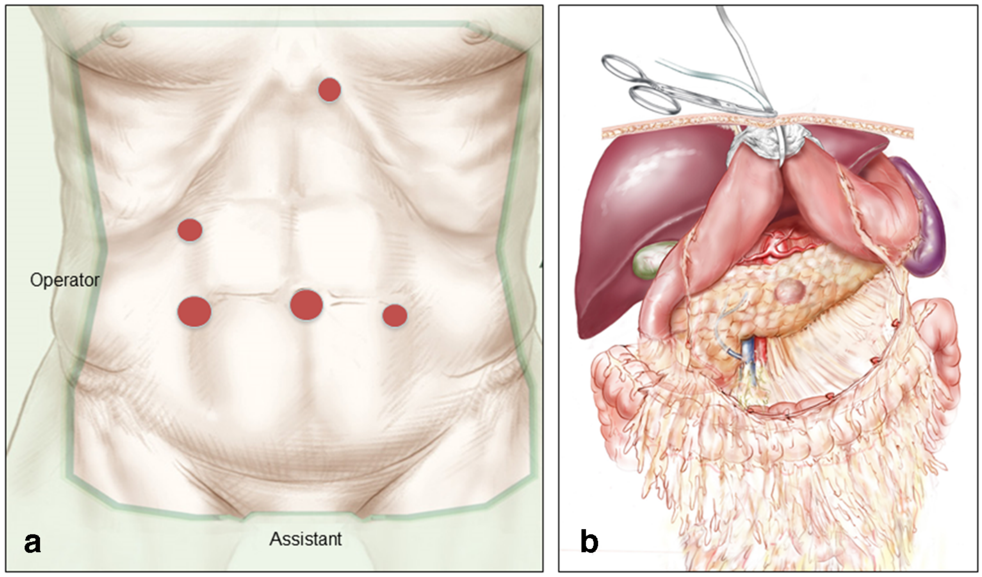


**Fig. 1** **a** Five trocars were used and the epigastric one was used for gastric hanging. **b** Gastric hanging: The stomach is turned along its horizontal axis and blocked with a gauze against the abdominal wall. The epigastric trocar is completely removed and the pancreas is well exposed

staple line 60 mm, Ethicon Endo-Surgery, Issy les Moulineaux, France), but in some patients, the pancreas cannot be controlled to be sectioned safely by stapler (inflammation, tumor invasion, proximity to the gastroduodenal artery, or difficulty to dissect from splenic vessels) and in this case, the pancreas was gradually divided using energy-based devices and the cut surface was treated by elective duct ligation (when possible) and interrupted stitches. For this study, the choice of stapler was not based on any preoperative randomization related to patient selection or pancreatic thickness at the level of section. Patients received one of the three types stapler cartridge: white (2.5 mm), blue (3.5), or green (4.1 mm) stapler cartridges without any randomization. However, after analyzing the effect of cartridge stapler size on the occurrence of POPF in the first 84 patients (28 in each group), no difference was found and then we decided to use the white or blue stapler and finally the blue of medium size to standardize and facilitate our daily practice.

## Drainage modality

Intra-abdominal drainage was used in all patients and in our practice LDP and ODP were drained by multi-tubular drain (Multitubular drain, Coloplast) (Fig. 2a), and the first 79 LDP had this drainage modality. However, after observing on postoperative CT that the multi-tubular drain had spontaneously moved from the surgical field in certain patients who later had an uneventful course with or without collections, we decided (since 2012) to use a small suction drain (Redon Nadel CH 14, B, Braun, Germany) (Fig. 2b) and the last 102 LDP had this drainage modality. Demographics, as well as operative and postoperative outcomes, were studied.

## Management of pancreatic fistula and collections

For the purpose of this study, all POPF was reviewed and classified according to the ISGPF (17) as summarized in Table 1. All grades of POPF were usually managed in the hospital until complete recovery. In patients with POPF and multi-tubular drainage and after postoperative day (POD) 7, the drain was gradually mobilized 2–3 cm every 2–3 days and removed completely by POD 10 in the absence of POPF and until healing in case of POPF. In patients with POPF and a small suction drain, the drain was removed by POD 7 if the drain was non-productive (most cases) otherwise, it was left in place until complete healing. Healing was defined by a zero output during two consecutive days. All patients received a

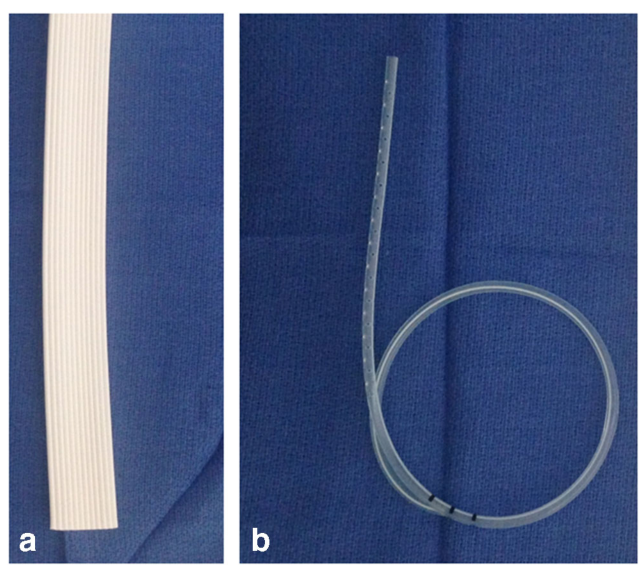


**Fig. 2** Drainage was done by multi-tubular drain **a** in the first period ($n$ = 79) and by a small suction drain **b** in the second period ($n$ = 102)

**Table 1** Different grades of postoperative pancreatic fistula (POPF) according to the International Study Group of Pancreatic Fistula

| Grade | A | B | C |
|---|---|---|---|
| Clinical condition | Well | Often well | Bad |
| Specific treatment for POPF | No | Yes/no | Yes |
| Peripancreatic collections on CT scan | No | Possible | Yes |
| Persistent drainage of POPF > 3 weeks | No | Usually yes | Yes |
| Re-intervention | No | No | Yes |
| Death related to POPF | No | No | Possibly yes |
| Signs of infections | No | Yes | Yes |
| Sepsis | No | No | Yes |
| Readmission | No | Yes/no | Yes/no |

postoperative CT scan at POD 7 and collections were measured whatever the size. Collections were regularly followed-up during imaging studies performed specifically for this purpose or for underlying pancreatic disease. Asymptomatic collections were observed whatever the size and patients underwent regular clinical, biological, and CT scan follow-up. Indications for drainage were large collections (> 10 cm) associated with clinical (pain, fatigue, prolonged fever, weight loss, and positive blood culture) and biological signs of infection. Patients with collections and good general status, slight fever (~ 38 °C) or moderate biological syndrome (leucocytosis and C-reactive protein) were observed. The indication of drainage cannot be based mainly on leukocytosis as splenectomized patients can have normal variations in the white blood count.

### Risk factors for clinically relevant pancreatic fistula

Complications were recorded as pancreatic-specific and certain patients developed more than one severe complication. Mortality included all deaths occurring within 90 days after surgery. Many risk factors for POPF were studied including: age (< or > 70 years), gender, body mass index (BMI), associated diabetes, underlying pathology (benign versus malignant), main pancreatic duct size (< or > 3 mm), thickness (measured by preoperative CT scan) of the pancreas (< or > 10 mm), level of pancreatic division (neck versus body-tail), associated splenectomy, different types of stapler, stapler closure versus ligation, and the type of drainage (multi-tubular drainage versus small suction drain). Subgroup analyses were performed with different types of stapler (white vs green, white vs blue, and blue vs green). Patients with clinically significant POPF (grades B and C) were compared to those with grade A or no POPF. Univariate and multivariate analyses were performed.

### Statistics

Values are expressed as means and ranges, or percentages, as appropriate. Qualitative variables were compared using chi-squared or Fisher's exact tests as appropriate. *P* values were adjusted in post hoc analysis using rcompanion package. Data normality was assessed using the Shapiro-Wilk test. According to data normality, analysis of variance (ANOVA) or Kruskal-Wallis test was used to compare between continuous variables. We used a post hoc test for multiple comparisons: Dunnett's T3 test after ANOVA and Dunn test with the 0.928 after Kruskal-Wallis. We used R (version 3.5.0) with FSA package.

## Results

During the study period, 181 patients underwent LDP and patient characteristics are summarized in Table 2. Indications for LDP were malignancy ($n = 68$; 38%) and low potential malignant and benign diseases ($n = 113$; 62%). Operative data are summarized in Table 2. In 68 patients, the splenic vessels were resected for oncological reasons ($n = 43$) or due to injury or severe inflammatory adhesions ($n = 25$). The postoperative outcome is summarized in Table 2. POPF were observed in 66 (36%) patients including 32 (18%) of grade B and nine (5%) of grade C.

### Analysis of pancreatic fistula and stapler cartridge size

The pancreas was divided by stapler in 130 (72%) patients. The comparison of the three groups of staplers (Table 3), showed no difference in demographic data and pancreatic section site characteristics (level of section, thickness, or the main pancreatic size) but more patients with the blue stapler were treated with a small suction drain (85 vs 23%, $p < 0.0001$). The blue stapler group showed a lower rate of grade B POPF ($p = 0.028$) and a shorter hospital stay ($p = 0.004$).

### Multi-tubular versus small suction drainage

Comparison of patients drained with multi-tubular drain to those with a small suction drain is summarized in Table 4. After a mean radiological follow-up of 22 months (1–108),

**Table 2** Demographics, surgical, and postoperative outcome for the all population

| Variables: mean (range); *n* (%) | Total = 181 |
|---|---|
| Age | 56 (18–87) |
| Gender: female /male | 112 (62); 69 (38) |
| Body mass index (kg/m$^2$) | 25 (17–39) |
| Comorbidities | 75 (41) |
| Intraductal papillary mucinous neoplasia | 49 (27) |
| Adenocarcinoma | 28 (16) |
| Mucinous cystadenoma (including one degenerated) | 20 (11) |
| Neuroendocrine tumor > 2 cm; < 2 cm | 19(11); 12 (7) |
| Solid and cystic pseudopapillary tumor | 11 (6) |
| Chronic pancreatitis | 10 (5) |
| Pan IN lesions and hereditary pancreatitis | 8 (4) |
| Degenerated intraductal papillary mucinous neoplasia | 7 (4) |
| Other benign or malignant diseases | 17 (9) |
| Operative time (mn) | 173 (60–410) |
| Blood loss (ml) | 241 (0–1500) |
| Intraoperative transfusion | 6 (3) |
| Conversion | 5 (3) |
| Hand assisted | 15 (8) |
| Splenectomy associated | 58 (32) |
| Without splenectomy: vessels preserving/vessels no preserving | 123 (68): 55 (45); 68 (55) |
| Length of the resected pancreas; length < 6 cm | 10 (3–18); 29 (16) |
| Section level: neck; body-tail | 78 (43); 103 (57) |
| Section by stapler | 130 (72) |
| White (2.5 mm), blue (3.5 mm), green (4.1 mm) | 47 (36); 55 (42); 28 (22) |
| Mortality | 0 |
| Overall morbidity | 95 (52) |
| Pancreatic fistula: overall, grade A, grade B, and grade C | 68 (38); 25 (14); 32 (18); 9 (5) |
| Bleeding | 11 (6) |
| Drained collections | 10 (6) |
| Re-intervention | 9 (5) |
| Pulmonary complications; cardiac complications | 10 (6); 4 (2) |
| Hospital stay | 15 (5–73) |

collections ($n = 81$) showed complete regression ($n = 72$, 89%), significant regression ($n = 8$; 10%), and increase in size (1, 1%).

## Univariate and multivariate analysis

On univariate and multivariate analysis (Table 5), the only protective factor for the development of grade B and C POPF ($n = 41$, 23%) was the presence of a small suction drain (6 vs 44%, odds ratio 7.385 (1.919–28.418); $p = 0.004$).

# Discussion

This study once again confirms that POPF is the main complication after DP whatever the approach. The reported incidence of POPF with ODP in certain randomized studies (36–62%) (18–21) and with LDP (57–60%) (22, 23) is still very high. This high rate POPF negatively influences the length of hospital stay and the overall cost of these procedures (11, 12). Risk factors of POPF with LDP should be studied to maximize the advantage of minimally invasive surgery.

The risk factors of POPF following DP can be related to the patient, the underlying pathology, the surgical technique, or the postoperative management. Many patient-related risk factors have been shown to increase the risk of POPF such as age < 65 years (24), high body mass index, high ASA score, low albumin (25), diabetes (26), and chronic pancreatitis (27). On cross-sectional images, a thick pancreas (> 15 mm) at the transected area can be diagnosed and significantly increase the risk of POPF (28, 29). However, preoperative chemoradiation (30) has been shown to decrease the risk of POPF. It is difficult or impossible to modify these preoperative factors to decrease the incidence of POPF. In a prospective randomized study, preoperative prophylactic trans-papillary pancreatic stent insertion was not effective in reducing the risk of clinically significant POPF (22 vs 42%, $p = 0.122$) (31). It was recently demonstrated that the administration of pasireotide on the morning of surgery and for 7 days significantly decreased the rate of clinically significant POPF, leaks, or abscess (32).

Many surgical techniques and devices have been described and developed to decrease the risk of POPF. Certain retrospective studies have shown that elective main pancreatic duct ligation (24) and section on the neck (14, 25) decrease the risk of POPF. At least three randomized multicenter controlled studies (19–21) did not show that the application of an absorbable fibrin sealant patch on the cut surface was effective after DP. In one of these studies, no difference was observed in the overall incidence (56 vs 71%, $p = 0.095$) or the development of clinically relevant POPF (28 vs 23%, $p = 0.536$) between the control and patch groups (21). In a French multicenter study, no difference (control vs patch) was observed in overall (55 vs 57%, $p = 0.807$) or clinically significant POPF (31 vs 24%, $p = 0.276$) (20). One recent randomized study showed that the use of polyglycolic acid mesh decreased the risk of clinically relevant POPF (11.4 vs 28.3, $p = 0.04$) (33). Covering the cut surface with a seromuscular jejunal layer (34) with the round ligament and fibrin glue (35) or adding pancreatico-enteral anastomosis (36) was not found to decrease the risk of clinically significant POPF. In a prospective randomized study, a teres ligament patch ($n = 76$) was shown to be a protective factor of clinically significant POPF compared to a control group (22 vs 33%; $p = 0.20$) (37). In all cases, rapid and bloodless surgery is recommended as prolonged surgery (> 480 min) (11) blood

**Table 3** Comparison of the three groups of staplers

| | Blue stapler (55) | White stapler (47) | Green stapler (28) | *P* |
|---|---|---|---|---|
| Mean age, mean (range) | 58 (19–87) | 53 (23–77) | 51 (18–78) | 0.201 |
| Age> 70 | 14 (26) | 6 (13) | 5 (18) | 0.26 |
| Gender | | | | |
| Female | 38 (69) | 26 (55) | 21 (75) | 0.089 |
| Male | 17 (31) | 21 (45) | 7 (25) | |
| Mean BMI, mean (range) | 25 (17–37) | 25 (18–39) | 24 (18–34) | 0.674 |
| BMI > 25 | 23 (42) | 21 (46) | 10 (39) | 0.747 |
| BMI > 30 | 11 (20) | 8 (17) | 1 (4) | 0.125 |
| Diabetes mellitus | 7 (13) | 9 (19) | 6 (21) | 0.519 |
| Malignant diseases | 15 (27) | 7 (15) | 4 (14) | 0.206 |
| Main pancreatic duct size | | | | 0.5443 |
| < 3 mm | 48 (87) | 44 (94) | 26 (93) | |
| > 3 mm | 7 (13) | 3 (6) | 2 (7) | |
| Thickness of the pancreas >1 cm | 49 (89) | 39 (83) | 24 (86) | 0.682 |
| Site of pancreas division: Isthmus | 29 (55) | 20 (43) | 9 (32) | 0.191 |
| Body | 26 (45) | 27 (67) | 19 (68) | |
| Associated splenectomy | 21 (38) | 19 (40) | 8 (29) | 0.570 |
| Abdominal drain. | | | | < 0.001 |
| Multi-tubular drain | 9 (16) | 36 (77) | 20 (71) | |
| Small suction drain | 46 (84) | 11 (23) | 8 (29) | |
| Operative time, mean (range) | 153 (60–300) | 169 (75–400) | 163 (75–285) | 0.472 |
| Blood loss (ml), mean (range) | 201 (0–850) | 229 (20–250) | 199 (30–800) | 0.793 |
| Overall morbidity | 23 (43) | 28 (60) | 17 (61) | 0.121 |
| Pancreatic fistula | | | | 0.373 |
| Grade A or no PF | 44 (85) | 32 (68) | 20 (71) | |
| Grades B and C | 8 (15) | 15 (32) | 8 (29) | |
| A | 5 (10) | 8 (17) | 7 (25) | 0.147 |
| B | 5 (10) | 13 (28) | 8 (29) | 0.021 |
| C | 3 (6) | 1 (2) | 0 | 0.540 |
| Collection, *n* (%) | 13 (25) | 9 (21) | 8 (38) | 0.639 |
| Drained collections, *n* (%) | 2 (4) | 3 (6) | 2 (7) | 0.688 |
| Bleeding, *n* (%) | 4 (8) | 6 (13) | 0 | 0.150 |
| Re-intervention | 2 (4) | 2 (4) | 0 | 0.681 |
| Respiratory complications | 1 (2) | 3 (6) | 1 (4) | 0.531 |
| Readmission | 5 (9) | 4 (9) | 2 (7) | 1 |
| Hospital length of stay (day), mean (range) | 12 (5–31) | 17 (6–70) | 16 (7–34) | 0.004 |

loss > 1 l and splenectomy have been shown to increase the risk of POPF (25).

In DP, the pancreas is either stapled or divided and the transected surface treated by stitches with or without elective main pancreatic duct ligation. Although certain older studies have shown an increased (11, 38, 39) or similar (40) incidence of POPF with a stapler, a large European multicenter randomized study (mainly with ODP) showed no difference in the rate of POPF (32 vs 28%, $p = 0.56$) when the cut surface was treated by stapler ($n = 221$) or hand sewn ($n = 229$) (18) after DP. With ODP, triple row versus double row staplers (41) and a reinforced stapler (42) were shown to be protective of POPF. In a randomized controlled study, staple line with mesh reinforcement ($n = 54$) compared to the control group ($n = 46$), showed a significant decrease in the rate of grades B/C POPF (1.9 vs 20%, $p = 0.007$) (43). Because studies showed no inferiority of stapler with ODP, its use became a valuable alternative during LDP because it is much more rapid than hand-sewn sutures with or without elective main pancreatic duct ligation.

Risk factors for POPF during the LDP have not been extensively studied. In one study, POPF (60%) was

**Table 4** Comparison of the postoperative outcome between multi-tubular drain small suction drains. Postoperative pancreatic fistula (POPF)

| Variables, *n* (%) | Multi-tubular drain *n* = 79 | Small suction drain *n* = 102 | *p* |
|---|---|---|---|
| Grade A POPF | 16 (20) | 9 (9) | 0.044 |
| Grade B POPF | 29 (37) | 3 (3) | < 0.001 |
| Grade C POPF | 6 (8) | 3 (3) | 0.188 |
| Collections observed on CT scan | 26 (33) | 55 (54) | 0.004 |
| Drained collections | 6 (8) | 4 (4) | 0.167 |
| Bleeding | 9 (11) | 2 (2) | 0.010 |
| Re-intervention | 4 (5) | 5 (5) | 0.997 |
| Re-admission | 5 (6) | 11 (11) | 0.268 |
| Hospital stay (days), mean (range) | 20 (7–73) | 11 (5–44) | < 0.001 |

more frequent in the presence of a thick pancreas (15.2 vs 13.5, $p = 0.002$) and a high BMI ($p = 0.003$) (23), while another study showed that it was more frequent when the pancreas is > 12 mm thick and in the presence of a soft pancreas (44).

Although the pancreas is stapled in most patients during LDP, the best stapler size has not been clearly identified. During ODP, a large cartridge (4.1 mm) was associated with POPF on multivariate analysis (26). With LDP, the best stapler cartridge to decrease POPF was 1.8 mm if the pancreas was < 12 mm thick but no suitable-sized cartridge was found for a thicker pancreas (23). Clinically relevant POPF developed in 15/64 patients (24%) operated by ODP (50%) or LDP (50%), and vascular type (2.5 mm) stapler cartridge size was associated with a lower risk of POPF than green staplers (4.5 mm) (5 vs 31%, $p = 0.04$) (45). In the present study, although there was no significant difference in the three groups regarding the size of the main pancreatic duct (< or >3 mm) nor the thickness of the pancreatic gland at the section level (< or >10 mm), on multivariate analysis, the stapler cartridge size did not influence the development of clinically significant POPF. The lower POPF grade B observed with the blue type was simply because this subgroup was more frequently drained with a small suction drain.

As POPF remains the most frequent and severe complication after pancreatic surgery, in our practice, DPs by both approaches were drained with multi-tubular drains and by small suction drain since 2012. Intraperitoneal drainage remains a major concern after abdominal surgery, especially pancreatic surgery. The utility of this drainage remains debatable because do not treat all complications, source of sepsis and percutaneous drainage can be needed. Many surgeons thought that intraperitoneal drainage may promote fistula, sepsis, and bleeding. Our study shows that a small suction drain significantly decreased the rate of POPF and the length of the hospital stay (Table 4). This type of drainage either actually decreases the incidence of POPF because the transected pancreas is rapidly covered by the surrounding structures or simply transforms POPF into asymptomatic collections because of insufficient drainage.

Numerous retrospectives studies have shown that routine drainage did not decrease postoperative complications in patients who underwent DP alone (46) or in all types of pancreatic resection including DP (47). In a recent study based on ACS-NSQIP data and propensity score analysis (116 vs 116), drainage of the surgical field was shown to increase the incidence of POPF ($p < 0.01$) and overall morbidity ($p < 0.05$) after DP compared to the group with no drain (48). It is very difficult to compare our type of drainage to the results in the literature because the type and time of removal are difficult to compare and not always reported. In a recent multicentric randomized study (49), 344 patients were randomized to undergo DP with ($n = 174$) or without ($n = 170$) intraperitoneal drainage after DP. LDP was done in 44% in each group. There was no difference in ≥ grade 2 complication (44 vs 42%, $p = 0.804$), grades B/C POPF (18 vs 12%, $p = 0.114$), mortality (0 vs 1%, $p = 0.24$), percutaneous drainage (10 vs 10%, $p = 0.916$), reoperation (5 vs 4%, $p = 0.456$), and readmission (24 vs 22%, $p = 0.69$). This study shows at least no inferiority of the non-drainage group.

All studies are concordant to demonstrate that the no drainage or drainage with small suction drain groups are associated with higher rate of collections. In our study, collections are more frequent with small suction drain compared to multi-tubular drain (54 vs 33%, $p = 0.004$), however, symptomatic collections needing percutaneous drainage was equally observed (4 vs 8%, $p = 0.167$). Our results are similar to literature data. Collections are frequent following DP, most are asymptomatic and resolve spontaneously (50). In a recent study, the occurrence of collections was evaluated with at least two cross-sectional imaging examinations in 159/209 patients who underwent

**Table 5** Univariate and multivariate logistic regression of risk factors influencing postoperative pancreatic fistula of grades B and C

| Variables | Grades B and C (total = 41) Nb (%) | *p* | Multivariate HR (CI 95%), *p* |
|---|---|---|---|
| Age | | | |
| < 70 years | 34 (24) | | |
| > 70 years | 7 (19) | 0.567 | |
| Gender | | | |
| Female | 28 (25) | | |
| Male | 13 (19) | 0.371 | |
| BMI | | | |
| > 25 | 24 (30) | 0.071 | |
| > 30 | 8 (26) | 0.761 | |
| Diabetes mellitus | | | |
| Yes | 8 (22) | | |
| No | 33 (23) | 0.897 | |
| Pathology | | | |
| Benign | 32 (28) | | |
| Malignant | 9 (15) | 0.048 | |
| Main pancreatic duct size | | | |
| > 3 mm | 3 (12) | | |
| < 3 mm | 38 (25) | 0.132 | |
| Modality of drainage | | | |
| Small suction drain | 6 (6) | | |
| Multi-tubular drain | 35 (44) | < 0.001 | 7.385 (1.919–28.418); 0.004 |
| Thickness of the pancreas | | | |
| > 1 | 36 (30) | | |
| < 1 cm | 5 (36) | 0.622 | |
| Site of pancreas division | | | |
| Isthmus | 18 (24) | 0.874 | |
| Body | 23 (25) | | |
| Splenectomy: | | | |
| Yes | 13 (23) | 0.969 | |
| No | 28 (23) | | |
| Blood loss (ml) | | | |
| < 400 | 33 (22) | 0.550 | |
| > 400 | 8 (28) | | |
| Operative duration | | | |
| < 360 mn | 40 (23) | 0.361 | |
| > 360 mn | 1 (50) | | |
| Stapler (white vs green) | | | |
| White | 15 (31) | 0.966 | |
| Green | 8 (31) | | |
| Stapler (white vs blue) | | | |
| White | 15 (32) | 0.052 | |
| Blue | 8 (15) | | |
| Stapler (blue vs green) | | | |
| Blue | 8 (15) | 0.160 | |
| Green | 8 (29) | | |
| Stapler of any size | 31 (24) | 0.445 | |
| Closure by duct ligation/stitches | 10 (19) | | |

DP. Collections were frequent (43%) but only 9% of patients required specific treatment (51). In the recent multicentric study on drainage (49), abdominal fluid collections (9 vs 22%, $p = 0.0004$) were more frequent in the no drainage group, and among the 53 patients with collections, only three (6%) needed percutaneous drainage.

The most important message and as we explained in our management of collections, is that indications for drainage should be very restricted and done only in really symptomatic patients. One can ask about the risk of bleeding with these residual collections, in our experience, although collections were frequent with small suction drain; however, bleeding was less frequently observed (2 vs 11%, $p = 0.01$). We did not specifically study the risk of infection, but theoretically, the risk of infection is probably lower with this small suction closed drain. After a few months of observation, asymptomatic collections disappear completely or decrease in size (Fig. 3). Usually, collections become symptomatic 3–4 weeks after surgery and at this time, collections are well organized and drainage is more frequently done by the endoscopic approach with a short hospital stay (1–2 days).

The mean hospital stay with the small suction drain was 11 days (5–44) because the small drain was not removed before day 7 following a CT scan. The relatively long hospital stay is explained by the fact that POPF is managed in hospital and consistent with European standards to keep patients until full recovery. On the other hand, the readmission rate is low (9%) compared with other studies where a readmission rate is at 24% (49) after DP or 29–32% after pancreatic surgery (52, 53). Our future strategy will be to remove the non-productive drain before day 5 and the hospital stay will certainly be shorter. One could question the use of this small suction drain because in most cases it is non-productive. Although in this study, we decided to shift from a large multi-tubular drain to a small one, LDP without a drain should also probably be evaluated.

This study had several limitations including its retrospective nature, performed on a period of 8 years, the choice of stapler cartridge size was not randomized, the small suction drain was used in the second period, and the management of the two drainage modalities was not similar. Our management of drainage is probably different from other teams and this modification could probably impact the results compared to other teams. We do not think that POPF is related to the learning curve nor the experience of the surgeon but probably with experience, LDP can be done rapidly and safely with better hemostasis.

In conclusion, the results of this large cohort suggest that the use of a small suction drain significantly decreases the rate of exteriorized POPF after LDP. Collections are frequent (> 50%) but remain asymptomatic (> 90%). The indications for drainage should be very restricted and if needed, the endoscopic trans-gastric approach becomes, probably, the standard. Observed collections disappear spontaneously within a few months with no increased risk of bleeding.


**Fig. 3** **a** Young female patient underwent laparoscopic short distal pancreatectomy for mucinous cystadenoma. **b** Postoperative CT scan showed large collection treated conservatively. **c** CT scan performed 13 months later showed complete spontaneous regression of the collection

## Compliance with ethical standards

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

**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

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