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Operative Drainage Following Pancreatic Resection:

Analysis of 1122 Patients Resected Over 5 Years at a Single Institution

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Abstract

Background—The only prospective randomized trial evaluating the use of intraperitoneal drainage following pancreatic resection was published from our institution approximately 10 years ago. The current study sought to evaluate the evolution of practice over the last 5 years.

Patients and Methods—Between June 2006 and June 2011, there were 1122 resections performed. Six surgeons were evenly grouped and compared by practice pattern: routine drainers (drains placed > 95%), selective drainers, and routine nondrainers (drains placed ~15%). Prospectively recorded preoperative, operative, and morbidity data were assessed in uni- and multivariate models.

Results—Our operative drainage rate was 49% and decreased over time (62% 2006–2008 vs 37% 2009–2011, $P < 0.001$). Patients without operative drains had significantly lower grade 3 overall morbidity (26% vs 33%; $P = 0.01$), shorter hospital stays (7 vs 8 days; $P < 0.01$), fewer readmissions (20% vs 27%; $P = 0.01$), and lower rates of grade 3 pancreatic fistula (16% vs 20%; $P = 0.05$). Similar reoperation (both <1%), interventional radiology procedures (15% vs 19%; $P = 0.1$), and mortality rates (2% vs 1%; $P = 0.3$) were seen in both groups. There were no differences between the routine drainers group ($n = 248$) and the nondrainers group ($n = 478$) in grade 3 fistula or need for interventional radiology-guided procedures.

Conclusions—In this study, operative drains were used nearly half of the time and were associated with longer hospital stay, and higher grade 3 morbidity, fistula, and readmission rates. They did not decrease the need for reintervention or alter mortality rates. Routine prophylactic drainage after pancreatic resection could be safely abandoned.

Keywords

distal pancreatectomy; drainage; pancreaticoduodenectomy; postoperative pancreatic fistula; pancreatic leak

For many years, the routine placement of surgical drains following abdominal operations has been considered standard practice.¹ However, over the last several decades, a gradual shift in practice toward abandonment of this approach has been prompted by a number of

randomized controlled trials that have tested the benefit of routine drainage of the operative bed. These studies have generally failed to identify any measurable benefit to routine drainage following liver,² gallbladder,³ gastric,^{4,5} and colorectal resection.^{6,7}

Pancreatic resection presents a unique challenge. Uncontrolled pancreatic fistula may result in catastrophic complications; therefore, early identification and control with surgically placed drains has been the rationale proposed in favor of routine drainage of the pancreatic bed. Given the significant improvements in imaging, endoscopy, and image-guided intervention, the practice of routine operative drainage after pancreas resection is open to challenge.⁸

Currently, the only randomized controlled trial to have evaluated the potential benefit and safety of routine drainage compared with no drainage after pancreatic resection was published from our institution in 2001.⁹ In that trial, the use of drains was associated with a similar rate of pancreatic fistula and a significantly higher incidence of intraabdominal infections compared with the no-drain group, suggesting that drainage should not be considered mandatory after pancreatic resection. These recommendations have not met widespread acceptance even at our own institution, and routine drainage is still practiced by the majority of pancreatic surgeons around the world.^{10,11} In this article, we evaluate our approach to operative drainage over the last 5 years, with a focus on development of pancreatic fistula, intraabdominal complications, and the need for postoperative interventions.

METHODS

A waiver of Health Insurance Portability and Accountability Act authorization and informed consent to perform this project was obtained through the Memorial Sloan-Kettering Cancer Center Institutional Review Board. The prospectively maintained pancreatic resection database was queried to identify patients who had undergone a formal partial pancreatic resection between June 2006 and June 2011. Demographic data were obtained from the electronic medical records. A synoptic operative report used at Memorial Sloan-Kettering Cancer Center itemizes information that is completed by the attending surgeon at the time of the operation and stores that information directly into the pancreas database. Prospectively collected data in our query included pancreatic parenchymal consistency, pancreatic and bile duct diameter, type of anastomosis, and the use and location of drains, as well as estimated blood loss, case length, and procedural complications.¹² Morbidity is recorded and graded in the Memorial Sloan Kettering Secondary Surgical Events program database,¹³ which uses a severity scale similar to others previously published,¹⁴ and consistent with the “Common Terminology Criteria for Adverse Events Version 4.0” endorsed by the National Institutes of Health and the National Cancer Institute. Data regarding management of complications, readmissions, and reinterventions were obtained by review of the medical records.

The 6 highest-volume pancreatic surgeons were paired according to their operative drainage practices into routine drainers (operative drains placed >95% of cases, total cases: 248), selective drainers (drains placed ~50% of cases, total cases: 348), and routine nondrainers (drains placed <15% of the time, total cases: 478). A multivariate logistic regression model

that included preoperative and operative variables with P values ≥ 0.25 in univariate analysis was built to identify predictors of the use of intraperitoneal drains in the “selective drainer” group.

Postoperative pancreatic fistula was defined as: pancreatic anastomotic leak (ie, clinical signs and symptoms or radiological confirmation of pancreatic anastomotic leak with amylase-rich drainage > 50 mL/d beyond postoperative day 5, without development of a fistula), pancreatic fistula (ie, clinical signs and symptoms with amylase-rich drainage > 50 mL/d beyond postoperative day 10), or intraabdominal abscess (ie, clinical signs and symptoms or radiological diagnosis of intraabdominal abscess or peritonitis) as coded in Memorial Sloan-Kettering Cancer Center’s Secondary Surgical Events program.¹⁵ These individual complications are then graded according to clinical management deviation, as shown in Table 1. Logistic regression was used to identify risk factors for the development of postoperative pancreatic fistula; independent models were built for pancreaticoduodenectomy and distal pancreatectomy.

Descriptive and comparative statistics were performed using SAS 9.2 software (SAS Institute Inc., NC). Continuous variables are reported as median and interquartile range unless otherwise specified, and were compared using the Student t test or Mann-Whitney test, as appropriate by the type of distribution. Categorical variables were compared using χ^2 or the Fisher exact test depending on the number of observations. A P value ≤ 0.05 was considered significant in all cases.

RESULTS

During the 5-year study period, a total of 1122 patients underwent a formal pancreatic resection (excluding total pancreatectomies and enucleations) by the 6 surgeons included in this study. Nearly half of the patients were men (49%) and the mean age at resection was 65 ± 13 years. Pancreaticoduodenectomy was the most common procedure performed (66%), followed by distal pancreatectomy (31%). There were 31 central and 2 central-sparing pancreatectomies, together comprising 3% of all resections (Table 2).

The most common diagnosis prompting an operation was pancreatic ductal adenocarcinoma, present in 458 of the 1122 patients (41%), followed by cystic neoplasms (including intraductal papillary mucinous neoplasm; mucinous cystic neoplasm; serous cystadenoma; and solid pseudopapillary neoplasm) comprising 15% and pancreatic neuroendocrine tumors comprising 12%.

Postoperative Complications

At least 1 complication was experienced in 51% of the patients in the cohort (573/1122) and these were clinically significant (ie, grade ≥ 3) in 59% (Table 3). Grade 5 complications (perioperative mortality) occurred in 18 patients for a mortality rate of 2%. The median length of stay for the cohort was 7 days (interquartile range: 6–9), and was longer in patients who developed complications [9 days (interquartile range: 7–14) vs 7 days (interquartile range: 6–8); $P < 0.001$]. Readmission occurred in 23% of patients and postoperative interventions were required in 18% (5 reoperations and 192 interventional radiology-guided

drainages). Overall and grade 3 morbidities were more commonly seen in patients who had operative drains placed (54% and 33% vs 48% and 26%, respectively; both $P < 0.05$).

Procedure-Specific Outcomes

Pancreaticoduodenectomy—Pancreaticoduodenectomy was performed in 739 patients. The most common diagnosis in this group was pancreatic ductal adenocarcinoma (47%; 345/739), followed by cystic neoplasms (15%; 108/739) and ampullary tumors (13%; 100/739). A preoperative biliary duct stent was present in 42% (308/739), and 7% required portal vein resection at the time of resection. The majority of patients (70%) had a pancreatic duct greater than 3 mm in diameter, and 52% had a soft gland (Table 4).

The median operative time for these patients was 250 minutes (interquartile range: 203–306), and estimated blood loss was 500 mL (interquartile range: 300–750). The median length of hospital stay was 8 days (interquartile range: 7–10). Grade 3–4 morbidity rate was 33%, the most common complications being pancreatic fistulae (18%), wound infections (7%), delayed gastric emptying (3%), and postoperative nausea (3%). Mortality after pancreaticoduodenectomy was 2% (14/739), most commonly secondary to postoperative sepsis and multiorgan system failure (8/14); other causes included ventricular arrhythmias (3/14), and liver failure, gastrointestinal bleeding, and bronchial aspiration in 1 case each.

Distal Pancreatectomy—Distal pancreatic resections were performed in 350 patients (31%), 43 of these using a laparoscopic approach. The most common diagnoses were ductal adenocarcinoma (32%), cystic neoplasms (25%), or pancreatic endocrine neoplasms (23%), and the majority underwent splenectomy (76%). Median estimated blood loss was 300 mL (interquartile range: 150–600). The pancreatic stump was most commonly stapled (72%), using a seamguard for reinforcement in 34% of these cases. The staple line was oversewn in 15%. When a stapler was not used (28%), the pancreatic stump was oversewn with duct ligation when possible. The median operative time was lower for open resections [165 min (interquartile range: 125–206) vs 190 min (interquartile range: 159–225); $P < 0.01$]; length of hospital stay, on the other hand, was shorter for patients undergoing laparoscopic distal pancreatectomy [5 days (interquartile range: 4–6) vs 6 days (interquartile range: 5–8); $P < 0.01$].

Following distal pancreatectomy, 27% of patients developed grade 3 or 4 morbidity; the most common complication was pancreatic fistula (20%). Twenty-three percent of patients were readmitted. Postoperative interventions were necessary in 20% (70/350) of patients; only 1 patient required reoperation. Multiorgan failure, complications derived from an uncontrolled pancreatic fistula, liver dysfunction, and cardiac arrest led to the demise of 1 patient each, for a mortality rate of 1% (4/350) in patients undergoing a distal pancreatectomy.

Use of Drains—Prophylactic intraperitoneal Jackson-Pratt drains were placed in 49% of patients overall (553/1122). Patients undergoing a pancreaticoduodenectomy were more likely to have an intraperitoneal drain placed at the time of resection compared with patients undergoing a distal pancreatectomy or other resections (52% vs 44% vs 39%; $P = 0.02$). Drains were more likely to be placed primarily during resections for cholangiocarcinoma

(26/39; 67%) and ampullary cancer (59/100; 59%) than during resections for pancreatic ductal adenocarcinoma or cystic neoplasms (48% and 43%, respectively).

Drainage practices changed over time. In the first half of the study (2006–2008), the drainage rate was 49%, while in the latter half (2009–2011), it decreased to 37% ($P < 0.01$). A pattern was found among the 6 highest-volume surgeons: 2 surgeons placed drains routinely (routine drainers: 248 cases), 2 surgeons rarely used drains (routine nondrainers: 478 cases), while a third pair of surgeons utilized drains in approximately half of their cases (selective drainers: 348). The decrease in drainage rates through the years was entirely accounted for by changing practices of selective drainers and nondrainers (Fig. 1). While routine drainers did not alter their drainage practices over time (97% 2006–2008 vs 94% 2009–2011; $P = 0.4$), selective drainers (85% 2006–2008 vs 46% 2009–2011; $P < 0.01$) and nondrainers (34% 2006–2008 vs 4% 2009–2011; $P < 0.01$) significantly reduced the use of drains.

Factors associated with the placement of drains in cases performed by selective drainers were analyzed in 2 independent uni- and multivariate models for pancreaticoduodenectomy and distal pancreatectomy, respectively (Table 5). After pancreaticoduodenectomy, drains were more likely placed in patients with bile ducts measuring $< 5\text{mm}$ (90% vs 59%; $P = 0.001$), in patients with larger amounts of blood loss (700 mL vs 500 mL; $P = 0.01$) and with longer operations (5.1 hours vs 4.6 hours; $P < 0.001$). Bile duct diameter and operative time remained significantly associated with drain placement in multivariate analysis.

After distal pancreatic resection, drains were less likely to be placed if the pancreatic remnant had been stapled (42% vs 72%; $P = 0.07$), but this did not reach statistical significance. As for proximal resections, patients who had drains placed had larger amounts of blood loss (650 mL vs 410 mL; $P = 0.05$) and longer operations (3.5 hours vs 2.9 hours; $P = 0.02$). None of these factors remained significantly associated with drain placement in multivariate logistic regression for distal pancreatectomy.

Postoperative Pancreatic Fistula—The overall rate of postoperative pancreatic fistula was 22% (251/1122), and the relative frequency was comparable among patients who had undergone pancreaticoduodenectomy (22%; 163/739) and distal pancreatectomy (23%; 80/350). Patients with operatively placed drains experienced fistulae more commonly than patients without them (27% vs 18%; $P < 0.01$) (Table 3).

The incidence of grade 3 fistulae was 18% (204 of 1122 patients). It was comparable among different procedures (17% pancreaticoduodenectomy and 20% distal pancreatectomy; $P = 0.4$), and remained stable throughout the study period (18% 2006–2008 vs 17% 2009–2011; $P = 0.7$) (Fig. 1). These were also more commonly diagnosed in patients with surgically placed drains (20% vs 16%; $P = 0.05$). Infected intraabdominal collections, or leaks with positive cultures, were found in 11% of patients (124/1122), more commonly in patients with operatively placed drains (13% vs 9%; $P = 0.04$).

Risk factors for developing grade 3 postoperative pancreatic fistula in patients undergoing pancreaticoduodenectomy included male sex (21% vs 13%; $P = 0.03$), resections performed

for a diagnosis other than ductal adenocarcinoma (11% vs 23%; $P < 0.001$), a soft gland (9% vs 26%; $P < 0.001$), and pancreatic duct diameter less than 3 mm (14% vs 17%; $P < 0.001$). These patients also had higher median blood loss [500 mL (300–750) vs 550 mL (400–900); $P = 0.01$] and longer operative times [4.1 hour (interquartile range: 3.3–5) vs 4.5 hour (interquartile range: 3.6–5.1); $P = 0.02$]. In multivariate analysis, gland consistency was the strongest predictor of development of a grade 3 fistula, with a hazard ratio 3 times higher for patients with soft glands; small pancreatic duct diameter and operative blood loss were also significant in this model (Table 6).

For patients undergoing distal pancreatectomy, male sex was the only predictor of high-grade pancreatic fistula (odds ratio 2.6, 95% confidence interval 1.5–4.5; $P < 0.01$). No significant predictors of pancreatic fistulae were identified for patients undergoing central pancreatic resections.

Readmissions and Additional Procedures—Overall, 23% of patients in the cohort required readmission. This was more common for patients who had drains placed at the time of operation (27% vs 21%; $P < 0.01$). Readmission rate for fistula-related complications was similar between patients who did and did not have prophylactic operative drains (64% vs 53%; $P = 0.1$). Percutaneous computed tomography-guided drainage was performed on 76% of patients after development of a fistula. Among them, patients with operatively placed drains required subsequent percutaneous procedures more commonly than patients who had not had prophylactic operative drains (85% vs 70%; $P = 0.01$). Reexploration was an uncommon event overall and was required with a similar frequency in patients with and without operative drains (<1%) (Tables 4 and 7).

Patients undergoing surgery by nondrainers and routine drainers had similar postoperative outcomes. The overall incidence of grade 3 to 4 complications (29% vs 27%; $P = 0.5$), grade 3 postoperative pancreatic fistula (17% vs 13%; $P = 0.1$), readmission (21% vs 24%; $P = 0.4$), interventional radiology-guided procedures (16% vs 12%; $P = 0.1$), and mortality rates (2% vs 1%; $P = 0.4$) were all comparable. Length of hospital stay, however, was shorter for nondrainers [7 days (interquartile range: 6–9) vs 8 days (interquartile range: 7–10); $P < 0.001$].

DISCUSSION

This nonrandomized study provides further evidence that routine operative drainage after pancreatic resection should not be considered mandatory. In this cohort, the overall pancreatic fistula rate was 22%, and lower in patients who did not have drains placed at operation (27% vs 18%; $P < 0.001$). Clinically relevant fistulae (grade 3) were also less common in these patients as was the incidence of infectious abdominal complications. In addition, the placement of operative drains in patients who did develop pancreatic leak/fistula did not appear to improve the ability to resolve the leak as a higher percentage of them required percutaneous intervention. Consistent with this fact, the readmission rate was higher in patients with prophylactic operative drains, and the need for reoperation and mortality rates was comparable to that of patients who did not have drains placed at the time of initial operation.

Our analysis revealed 3 operative drainage practices at our institution: routine drainage, selective drainage, and routine nondrainage. These practices are largely determined by individual surgeon's bias and, with the exception of the routine drainers, have changed to less frequent use of prophylactic operative drains over time. We tried to determine the factors that influence the decision to place drains in cases performed by selective drainers, as routine drainers and nondrainers either placed or omitted drains in nearly all cases. In multivariate analysis, a bile duct <5mm and a longer duration of surgery were associated with drain placement in pancreaticoduodenectomy. We failed to identify any predictors of drain placement in the multivariate logistic model for distal pancreatectomy. Nevertheless, case length was associated with drain placement in univariate analysis, suggesting that perhaps as a surrogate marker of more challenging cases, long operative times may influence the surgeon's decision to drain the pancreatic bed.

The 18% rate of clinically significant postoperative pancreatic fistula in this cohort is similar to what is generally reported in the literature.^{10,16–18} Factors associated with the occurrence of fistulae included a soft gland and small duct size, in addition to operative blood loss for patients who underwent pancreaticoduodenectomy. Only male sex seemed to be associated with an increased risk for development of clinically significant postoperative pancreatic fistula after distal pancreatectomy.

The management of operative drains has been the subject of many recent reports.^{11,19–21} The Verona group has recently published a well-designed trial comparing early (postoperative day 3) versus late (postoperative day 5 or later) drain removal, concluding that early drain removal in patients at low risk for fistula was safe. Prolonged drainage was associated with higher postoperative complication rates and prolonged hospital stays. Interestingly, in patients who had early drain removal, there was a significantly lower rate of other intraabdominal and pulmonary complication rates. In multivariate analysis, timing of drain removal was the strongest predictor independently associated with postoperative pancreatic fistula.¹⁹ Their study does not support the conclusion that drains should not be routinely used after pancreatic surgery; however, it does provide very valuable data underscoring the potential negative effects derived from the routine and prolonged use of operative drains.

In a recently published study, Fisher et al report results from a prospective cohort of 47 consecutive patients undergoing pancreatic resection without operative drainage and compared their outcomes with a historical cohort of 179 consecutive patients.⁸ They found that patients who had prophylactic operative drains placed had higher overall complication rates and complication severity scores. Clinically significant fistula rates were similar between the 2 groups; however, patients without operatively placed drains had higher readmission and interventional radiology procedure rates. Mortality and reoperation rates were equivalent.

In the absence of physiological data, it is difficult to argue that drainage catheters cause pancreatic fistula; however, their routine use may have negative effects. Routine intraperitoneal drainage might identify small and transient elevations in amylase that would otherwise be clinically inconsequential and thus prompt unnecessary investigations and

interventions. Additionally, multiple reports and prospective trials have suggested that percutaneous drains may create a pathway for retrograde infection,^{2,8,22,23} and as was found in the present article, they have been shown to be associated with development of intraabdominal infectious complications.

A randomized controlled trial evaluating the ability of surgically placed drains to reduce postoperative complications or death after pancreatic resection was published from our institution in 2001. In that study, Conlon et al failed to show a decreased incidence of pancreatic fistula in patients with surgically placed drains. On the contrary, these patients experienced intraabdominal complications more often than their counterparts without drains. As in our present article, the need for reinterventions (surgical or percutaneous) was similar between the 2 groups. Ultimately, perhaps the most compelling argument that can be offered to support abandoning routine drainage after pancreatic resections is that the devastating complications that are feared to be associated with uncontrolled leaks (sepsis, postpancreatectomy hemorrhage, death) have not been found to be more easily managed in patients who have had drains placed at operation.

One of the major strengths of this study is the fact that single-institution comparisons could be made between high-volume pancreatic surgeons who almost always place drains and high-volume pancreatic surgeons who almost never place drains. Patient referral patterns, patient characteristics (age, comorbidities, duct size, etc), postoperative recovery pathways, postoperative interventional and endoscopic support, and time frame of the study were all similar between patients treated by routine drainers and nondrainers. These factors strengthen the comparison made between 2 largely homogeneous groups undergoing treatment at the same institution under very similar conditions. It is necessary to emphasize that the results of this study should only be extrapolated to centers with similar in-house diagnostic and interventional resources readily available 24 hours a day.

One of the weaknesses of any study that reports pancreatic fistula rates is the matter of definition. This study did not use the International Study Group for Pancreatic Fistula-defined criteria for postoperative pancreatic fistula.²⁴ Our system is very similar, and pancreatic fistula is defined by the presence of amylase-rich fluid for those patients with drains and graded according to severity; however, it also includes patients with intraabdominal collections and abscesses, being thus more inclusive. This is particularly relevant because a significant proportion of our patients without operative drains placed would be missed by the International Study Group for Pancreatic Fistula definition alone. We had implemented a prospective morbidity reporting system prior to the publication of the International Study Group for Pancreatic Fistula guidelines that includes both specific definitions and grading for the common complications following pancreatic surgery and have thus utilized this now validated system for complication reporting.^{13,15}

Two decades have passed since the initial reports of safe pancreatic resection without drainage^{25,26} and over 10 years since have passed since the first randomized controlled trial was published. Pancreatic bed drainage is still considered standard practice in many (if not most) pancreatic surgery centers and another randomized trial is being discussed. Practice at

our own institution is evolving, and additional level I data would be helpful to further guide this transition in practice.

CONCLUSION

The results of this study suggest that routine drainage of the operative bed is not associated with improved outcomes. Patients who had operative drains placed did not experience decreased rates of pancreatic fistula, and when pancreatic fistulae occurred, the placement of drains at the initial operation was not associated with decreased postoperative procedures, readmission rates, reoperative rates, overall morbidity, or mortality. Current level I and level II evidence does not support routine drainage of the operative bed following pancreatectomy and suggests that operative drainage may be associated with higher rates of infectious complications.

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FIGURE 1.

Use of operative drains and grade 3 fistula rates. Lines: Prophylactic drainage trends over years per surgeon type. Bars: Incidence of grade 3 fistula overall. RD, routine drainers; SD, selective drainers; ND, nondrainers.

TABLE 1**Definition and Grading of Pancreatic Fistula, Leak, and Abscess**

Complication	Grade	
Pancreatic fistula Clinical signs/symptoms with amylase-rich drainage > 50 mL/d beyond postoperative day 10	1	Oral medication or bedside medical care required
	2	IV medical therapy with resolution or antibiotics or TPN required
	3	IR, endoscopic, or operative intervention required
	4	Chronic deficit or disability associated with the event
	5	Death associated with sequelae of this event
Anastomotic leak, pancreas Clinical signs/symptoms or radiologic confirmation of pancreatic anastomotic leak with amylase-rich drainage > 50 mL/d beyond postoperative day 5, without development of a fistula	1	Oral medication or bedside medical care required
	2	IV medical therapy with resolution or antibiotics or TPN required
	3	IR, endoscopic, or operative intervention required
	4	Chronic deficit or disability associated with the event
	5	Death associated with sequelae of this event
Intraabdominal abscess Clinical signs/symptoms or radiologic diagnosis of intraabdominal abscess or peritonitis	1	Oral medication or bedside medical care required
	2	IV medical therapy with resolution or antibiotics or TPN required
	3	IR, endoscopic, or operative intervention required
	4	Chronic deficit or disability associated with the event
	5	Death associated with sequelae of this event

mL/d indicates milliliters per day; IV, intravenous; TPN, total parenteral nutrition; IR, interventional radiology.

TABLE 2**Demographics and Diagnoses**

	Total, n (%)
Total patients	1122
Age, mean $\pm$ SD	65 $\pm$ 13
Sex	
Male	548 (49%)
Female	574 (51%)
Operation	
Pancreaticoduodenectomy	739 (66%)
Distal pancreatectomy	350 (31%)
Central pancreatectomy	31 (2%)
Central-sparing pancreatectomy	2 (<1%)
Diagnoses	
PDAC	458 (41%)
Cystic lesion	173 (15%)
PNET	133 (12%)
Ampullary cancer	100 (9%)
Duodenal cancer	56 (5%)
Cholangiocarcinoma	39 (3%)
Pancreatitis	17 (2%)
Other	146 (13%)

SD indicates standard deviation; PDAC, pancreatic ductal adenocarcinoma; PNET, pancreatic neuroendocrine tumor.

TABLE 3**Postoperative Pancreatic Fistula and Top 3 Most Common Other Complications**

	Drain n = 553	No Drain n = 569	Total n = 1122	P
Postoperative pancreatic fistula, n (%)				
All grades	149 (27)	102 (18)	251 (22)	<0.001
Grade 1—2	36 (6)	11 (2)	47 (4)	<0.001
Grade 3	113 (20)	91 (16)	204 (18)	0.05
Infected collection or fistula	72 (13)	52 (9)	124 (11)	0.04
Non-fistula related complications				
Overall				
All grades	301 (54)	272 (48)	573 (51)	0.03
Grades 3—5	185 (33)	150 (26)	335 (30)	0.01
Top 3 most common grade 3–5:				
Postpancreatectomy hemorrhage	18 (3)	15 (3)	33 (3)	0.7
Delayed gastric emptying	8 (1)	9 (2)	17 (2)	0.9
Wound infection	11 (2)	5 (1)	16 (1)	0.2

TABLE 4

Pancreaticoduodenectomies

Total, n (%)	Drain, 386 (52)	No Drain, 353 (48)	Total (n = 739)	P
Diagnoses				0.07
PDAC	168 (49)	177 (51)	345	
Cystic lesion	49 (45)	59 (55)	108	
Ampullary cancer	59 (59)	41 (41)	100	
Duodenal cancer	29 (53)	26 (47)	55	
PNET	29 (64)	16 (36)	45	
Cholangiocarcinoma	26 (67)	13 (33)	39	
Pancreatitis	5 (42)	7 (58)	12	
Other	21 (60)	14 (40)	35	
Operative data				
Preop-stent (n = 699)*	162 (53)	146 (47)	308	0.1
PV resection (n = 739)*	30 (56)	24 (44)	54	0.3
Consistency (n = 590)*				0.04
Hard	122 (43)	164 (57)	286	
Soft	156 (51)	148 (49)	304	
Anastomosis (n = 736)*				0.6
Duct to mucosa	374 (52)	339 (48)	713	
Pancreaticogastrostomy	8 (50)	8 (50)	16	
Invaginated	3 (60)	2 (40)	5	
Other	0	2 (100)	2	
Duct size (n = 606)*				0.07
Small (<3mm)	94 (52)	88 (48)	182	
Intermediate (3–7mm)	157 (46)	188 (54)	345	
Large (>7mm)	32 (40)	47 (60)	79	
EBL median (IQR)	525 (350–800)	400 (250–700)	500 (300–750)	<0.001
Duration median minutes (IQR)	295 (250–339)	206 (180–247)	250 (203–306)	<0.001
Postoperative outcomes				
LOS, median (IQR)	8 (7–11)	7 (6–10)	8 (7–10)	<0.01
Readmission	107 (28)	73 (21)	180 (24%)	0.02
Grade 3–4 morbidity	139 (36)	105 (30)	244 (33%)	0.07
Mortality	3 (1)	11 (3)	14 (2%)	0.02
IR drainage	68 (18)	49 (14)	117 (16%)	0.2
reoperation	2 (<1%)	2 (<1%)	4 (<1%)	0.9
Pancreatic fistula				
All grades	104 (27)	59 (17)	163 (22)	0.001
G. 1–2	30 (8)	7 (2)	37 (5)	<0.001
G. 3	74 (19)	52 (15)	126 (17)	0.1

PDAC indicates pancreatic ductal adenocarcinoma; PNET, pancreatic neuroendocrine tumor; PV, portal vein; EBL, estimated blood loss; IQR, interquartile range; LOS, length of stay; IR, interventional radiology.

TABLE 5

Distal Pancreatectomies

Total, n (%)	Drain, 154 (44)	No Drain, 196 (56)	Total (n = 350)	P
Diagnoses, n (%)				0.1
PDAC	54 (48)	58 (52)	112	
Cystic lesion	30 (34)	58 (66)	88	
PNET	43 (54)	36 (46)	79	
Metastasis	11 (39)	17 (61)	28	
Pancreatitis	2 (40)	3 (60)	5	
Duodenal cancer	0	1 (100)	1	
Other	14 (38)	23 (62)	37	
Operative data				
Splenectomy				0.2
Spleen preserving	31 (37)	52 (63)	83	
With splenectomy	123 (46)	144 (54)	267	
Duct size (n = 161)				0.02
Small	37 (33)	74 (67)	111	
Intermediate	7 (14)	42 (86)	49	
Large	1 (100)	0	1	
Stump closure (n = 335)				0.6
Stapled	108 (44)	135 (56)	243	
Oversewn	38 (41)	54 (59)	92	
EBL median (IQR)	400 (200–800)	200 (100–400)	300 (150–600)	<0.001
Duration median (IQR)	191 (154–229)	152 (118–188)	168 (130–210)	<0.001
Postoperative outcomes				
LOS, median (IQR)	7 (6–9)	5 (5–7)	6 (5–8)	<0.01
Readmission	40 (26)	41 (21)	80 (23%)	0.3
Grade 3–4 comp	50 (32)	43 (22)	93 (27%)	0.03
Mortality	3 (2)	1 (<1)	4 (1%)	0.2
IR drainage	35 (23)	34 (17)	69 (20%)	0.2
Reoperation	1 (<1%)	0	1 (<1%)	0.3
Pancreatic fistula				
All grades	42 (27)	38 (19)	80 (23)	0.1
G. 1–2	6 (4)	3 (1)	9 (3)	0.3
G. 3	36 (23)	35 (18)	71 (20)	0.2

PDAC indicates pancreatic ductal adenocarcinoma; PNET, pancreatic neuroendocrine tumor; EBL, estimated blood loss; IQR, interquartile range; LOS, length of stay; IR, interventional radiology.

TABLE 6

Factors Influencing Drain Placement in Selective Drainers

Variables	Pancreaticoduodenectomy (n=237)				Distal Pancreatectomy (n=101)			
	Univariate		Multivariate		Univariate		Multivariate	
	P	P	HR (95% CI)	P	P	P	HR (95% CI)	P
Age	0.4			0.3				
Male sex	0.1	0.9	0.97 (0.5–2.1)	0.1	0.3		2.8 (0.4–19)	
PDAC	0.1	0.2	0.6 (0.2–1.3)	0.09	0.2		4.6 (0.5–41)	
Classic vs. pylorus-preserving PD	0.7			n/a				
Preoperative biliary stent	0.7			n/a				
Portal vein resection	0.5			n/a				
Splenectomy	n/a			0.07	0.7		0.6 (0.1–5)	
Stapled remnant closure	n/a			0.07	0.07		0.1 (0.1–1.2)	
Soft gland	0.1	0.8	1.1 (0.4–2.6)	n/a				
Pancreatic duct size <3mm	0.4			0.2	0.5		0.5 (0.1–3.4)	
Bile duct size <5mm	0.004	0.005	6.3 (1.7–23)	n/a				
Operative transfusion	0.5			n/a				
Estimated blood loss (100 mL)	0.02	0.5	1.02 (0.95–1.1)	0.06	0.7		0.9 (0.7–1.3)	
Case Length (1 hour)	0.001	0.008	1.8 (1.2–2.9)	0.02	0.2		2.9 (0.6–14)	

HR indicates hazard ratio; CI, confidence interval; PDAC, pancreatic ductal adenocarcinoma; PD, pancreaticoduodenectomy; n/a, not applicable.

TABLE 7
Uni- and Multivariate Analysis of Factors Associated With Development of Grade 3 Postoperative Pancreatic Fistula

Variables	Pancreaticoduodenectomy				Distal Pancreatectomy			
	Univariate		Multivariate		Univariate		Multivariate	
	P	OR (95% CI)	P	HR (95% CI)	P	OR (95% CI)	P	HR (95% CI)
Age	0.07		0.7		0.5			
Male sex	0.003	1.8 (1.2–2.7)	0.2		<0.01	2.8 (1.6–4.8)	0.001	2.6 (1.5–4.5)
PDAC	<0.001	0.4 (0.3–0.6)	0.2		0.7			
Classic vs. pylorus-preserving PD	0.1		0.6		n/a			
Laparoscopic distal pancreatectomy	n/a				0.3			
Preoperative biliary stent	0.3				n/a			
Portal vein resection	0.9				n/a			
Splenectomy	n/a				0.6			
Stapled remnant closure	n/a				0.15		0.7	
Soft gland	<0.001	3.3 (2.1–5.3)	<0.001	3.2 (1.9–5.3)	n/a			
Pancreatic duct size <3mm	<0.001	2.4 (1.6–3.7)	0.02	1.7 (1.1–2.8)	n/a			
Bile duct size	0.2		0.3		n/a			
Operative drains	0.1		0.8		0.2		0.2	
Operative transfusion	0.9				0.8			
Estimated blood loss	0.01	1.03 (1.01–1.1)	0.001	1.1 (1.03–1.1)	0.8			
Case length	0.02	1.2 (1.02–1.4)	0.9		0.29			

OR indicates odds ratio; HR, hazard ratio; CI, confidence interval; PDAC, pancreatic ductal adenocarcinoma; PD, pancreaticoduodenectomy; n/a, not applicable.