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Original Research Article

The power of suction: Theory and practice in closed suction vs gravity drains and postoperative pancreatic fistulas

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ABSTRACT

Background: Postoperative pancreatic fistula (POPF) is a feared complication in pancreatic resection. Gravity drainage (GD) is hypothesized to reduce POPF versus closed-suction drainage (CSD). We sought to evaluate this theory.

Methods: Six-hundred-twenty-nine patients undergoing pancreatic resection between 2013 and 2020 were analyzed with multivariable logistic regression for the outcomes of POPF and clinically-relevant POPF (crPOPF).

Results: Three-hundred-ninety-seven patients (63.1%) underwent pancreaticoduodenectomy and 232 (36.9%) underwent distal pancreatectomy. Suction drains were placed in 588 patients (93.5%) whereas 41 (6.5%) had GDs. One-hundred-twenty-five (27.6%) experienced a POPF; 49 (10%) crPOPFs. On multivariable analysis, suction drainage was not associated with increased risk of POPF (OR 0.76, 95% CI 0.30–1.93, P = 0.57) or crPOPF (OR 0.99, 95% CI 0.30–3.26, P = 0.98).

Conclusion: Suction drainage does not promote POPF when compared to GDs. Drain type should be determined by surgeon preference, while taking into account nursing and patient-specific considerations especially when patients are discharged with drains.

1. Introduction

In patients undergoing abdominal operations, placement of surgical drains aims to continuously extract fluids from the operative site, theoretically allowing for earlier identification of leaks or prevention of undrained fluid collections. This goal is uniquely important in pancreatic resections, where pancreatic fluid can leak from the pancreatic anastomosis or the cut edge of the pancreas, resulting in benign biochemical leaks or morbid postoperative pancreatic fistulas (POPF). The question of routine drain placement in pancreatic resection remains debated, although routine placement of drains with early discontinuation remains commonplace.[1,2,3,4]

In patients who do have surgical drains placed, there are two predominant methods of drainage: gravity drains and closed-suction drains (CSDs). Suction drains utilize a negative pressure gradient to maintain suction within the abdomen, independent of positioning, while gravity drainage devices provide a route for fluid extraction due to the pressure differential between intra-abdominal and atmospheric pressure. The presence of surgical drains has been shown to hinder post-operative mobilization,[5] and ERAS pathways commonly suggest minimizing surgical drain placement when appropriate.[6] Whether the specific attributes of GDs and CSDs impact ease of care and alters patients' ability to mobilize remains unclear, and preferences for drain method vary between providers.

Importantly, whether drainage method influences postoperative outcomes is poorly studied. Some studies have cited reduced length of stay[7,8] and diminished need for percutaneous intervention[9,10,11] with CSD, while others have noted an increased risk of surgical site infection (SSI) with CSD.[11,12] The negative pressure gradient created by CSDs has been posited by some clinicians to lead to an increased rate of POPF. Recent articles show similar POPF rates when CSDs and gravity drains are used,[9,10,11,13,14] however, there are a multitude of patient-level factors that may be associated with POPF that are not fully accounted for by these studies, including those that utilize NSQIP data which does not capture estimated blood loss (EBL) for pancreatic operations, a well-known risk factor for POPF. Very few studies exist which analyze

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Table 1
Clinicopathologic characteristics of patients undergoing pancreatic resection analyzed by drainage method.

Variable	Gravity Drainage (n = 41)	Closed Suction Drainage (n = 588)	Total (n = 629)	P Value
Age, Years; median [IQR]	64 [57–73]	65 [56–72]	65 [56–72]	0.93
Gender				0.01
Female	13 (31.7)	303 (51.5)	316 (50.2)	
Male	28 (68.3)	285 (48.5)	313 (49.8)	
Body Mass Index, kg/m^2; median [IQR]	28.0 [23.7–33.2]	27.3 [23.8–31.7]	27.4 [23.8–31.8]	0.67
ASA Class				0.94
ASA 1/2	11 (26.8)	180 (30.6)	191 (30.2)	
ASA 3/4	30 (73.2)	408 (69.4)	438 (69.8)	
Reason for Resection				0.04
Duodenal/Ampullary/Cholangiocarcinoma	12 (29.2)	82 (14.0)	94 (14.9)	
Benign Neoplasm/Chronic Pancreatitis	8 (19.6)	130 (22.1)	138 (21.9)	
PDAC	15 (36.6)	267 (45.4)	282 (44.8)	
PNET	6 (14.6)	109 (18.5)	115 (18.3)	
Neoadjuvant Chemotherapy	9 (22.0)	132 (22.4)	141 (22.4)	>0.99
Operation				<0.001
Whipple	30 (73.2)	367 (62.4)	397 (63.1)	
Distal Pancreatectomy or RAMPS	11 (26.8)	221 (37.6)	232 (36.9)	
Minimally Invasive Approach	2 (4.9)	115 (19.6)	117 (18.6)	0.20
Pancreas Texture				<0.001
Hard	18 (43.9)	137 (23.3)	155 (24.6)	
Not specified	6 (14.6)	295 (50.2)	301 (47.9)	
Soft	17 (41.5)	156 (26.5)	173 (27.5)	
Vascular Resection	5 (12.2)	102 (17.3)	107 (17.0)	0.52
Duct Size				0.30
<3 mm	12 (29.3)	224 (38.1)	236 (37.5)	
>6 mm	6 (14.6)	59 (10.0)	65 (10.3)	
3–6 mm	18 (43.9)	196 (33.3)	214 (34.0)	
Not Specified	5 (12.2)	109 (18.5)	114 (18.1)	
Estimated Blood Loss, mL; median [IQR]	350 [200–900]	600 [300–1000]	525 [300–1000]	0.83
Intraoperative Crystalloid, mL; median [IQR]	8875 [6500–11585]	5950 [3900–9000]	6000 [4000–9100]	<0.001
Length of Operation, Hours; median [IQR]	8.5 [6.4–10.0]	7.1 [4.9–8.8]	7.2 [5.1–8.9]	0.006
Pasireotide Administered	29 (70.7)	52 (8.8)	81 (12.9)	<0.001
Length of Stay, Days; median [IQR]	7 [7–12]	9 [7–13]	9 [7–13]	0.36
Days of Drainage; median [IQR]	7 [5–12]	6 [4–10]	6 [4–10]	0.30
POD 3–4 Amylase, U/L; median [IQR]	82 [20–651]	26 [9–205]	28 [9–234]	0.29

Abbreviations: IQR=Interquartile Range; ASA = American Society of Anesthesiologists; RAMPS = Radical Antegrade Modular Pancreatosplenectomy; IPMN=Intraductal Papillary Mucinous Neoplasm; SPEN=Solid Pseudopapillary Epithelial Neoplasm; PDAC=Pancreatic Ductal Adenocarcinoma; PNET=Pancreatic Neuroendocrine Tumor; POD=Postoperative Day.

NSQIP data by drainage method, and those that have neglect important outcome-related factors such as estimated blood loss and pasireotide administration.[11,12,15] Additionally, there is little data on the relationship between drain placement and type as they pertain to risk of biochemical leak (formerly Grade A POPF) with existing studies calling for further exploration on the topic.[12] To that end, we aimed to evaluate this question at our high-volume pancreas center.

2. Methods

2.1. Patient population and data source

All patients having undergone pancreatic resection from January 2013 through April 2020 were identified through our institutional National Surgical Quality Improvement Project (NSQIP) database. Standard outcome measures as per NSQIP, including pancreatectomy-targeted variables, such as POPF, were identified via the NSQIP database. Further chart review was completed to capture data on pasireotide usage and estimated blood loss. All patients had surgical drains placed, and patients were grouped by drainage method for analysis. Regardless of drainage method, all surgical drains were either 19-French silicone Blake 4-channel drains or the 20 cm by 10 mm Jackson-Pratt silicone full-perforated drains.

2.2. Outcomes and statistical evaluation

The primary outcomes assessed in this study were the presence of any biochemical leak or POPF, clinically relevant POPF (crPOPF), and need for percutaneous drainage. The definitions used for biochemical leak and crPOPF were those provided by the International Study Group on Pancreatic Fistulas (ISGPF) which defines crPOPF as "drain output of any measurable volume of fluid with an amylase level greater than three times the upper limit of institutional normal serum amylase activity, associated with a clinically relevant development/condition related directly to the postoperative pancreatic fistula".[16] The ISGPF also renamed what was formerly known as a Grade A POPF to "biochemical leak" as it is not associated with meaningful alterations in postoperative course. We also evaluated drain amylase levels on postoperative day 3 or 4 by drainage method.

Descriptive statistics of clinicopathologic variables were tabulated. Continuous variables were analyzed using medians with interquartile ranges (IQRs) and Student's t-test was done for intergroup comparisons. Fisher's exact and Chi-squared testing were performed as appropriate to analyze categorical variables by group. Single-variable logistic regression was used to evaluate odds of occurrence of each primary outcome, and multivariable logistic regression was performed including all of the clinicopathologic variables with $P < 0.02$ on univariable analysis. Those with $P < 0.02$ on univariable were included in initial multivariable modeling. Final multivariable models were chosen by single backwards elimination of variables that did not meet the threshold of statistical significance until further elimination would reduce model fit with $P < 0.05$.

The variable of drain type was added to the multivariable models for each primary outcome (POPF and crPOPF). All reported P values were two-sided and $P < 0.05$ was considered the threshold for statistical significance. Statistical analyses were carried out in SPSS Version 26 (IBM Corp, Armonk, NY). The protocol of this study was given approval by our Institutional Review Board (IRB) and was conducted in accordance with

Table 2
Odds of clinically relevant postoperative pancreatic fistula in patients undergoing pancreatectomy.

Variable	Univariable OR (95% CI)	P value	Multivariable OR (95% CI)	P value
Age (per year)	0.99 (0.97–1.01)	0.14	*	
Male Sex	1.79 (1.03–3.11)	0.04	1.67 (0.95–2.94)	0.08
ASA 3/4	0.91 (0.51–1.62)	0.75		
Whipple	0.84 (0.49–1.45)	0.53		
EBL (per liter)	1.25 (1.09–1.43)	0.001	1.29 (1.12–1.49)	0.001
Intraoperative Crystalloid Given (per liter)	1.09 (1.04–1.15)	0.001	*	
Operative Duration (per hour)	1.08 (0.99–1.18)	0.07	*	
Pasireotide Administered	1.85 (0.94–3.67)	0.08	*	
Duct Size (per mm)	0.87 (0.74–1.03)	0.10	*	
Soft Gland	2.36 (1.05–5.30)	0.04	1.57 (0.87–2.83)	0.14
PDAC or Chronic Pancreatitis	0.52 (0.29–0.91)	0.02	0.49 (0.27–0.89)	0.02
Minimally Invasive	1.13 (0.58–2.21)	0.72		
Vascular Reconstruction	1.28 (0.65–2.50)	0.48		
Neoadjuvant Chemotherapy	0.87 (0.45–1.70)	0.69		
Closed Suction Drainage	0.73 (0.27–1.93)	0.52	0.86 (0.32–2.34)	0.76

*Removed during single backwards elimination.
Abbreviations: OR=Odds Ratio; CI=Confidence Interval; ASA = American Society of Anesthesiologists; PDAC=Pancreatic Ductal Adenocarcinoma; EBL = Estimated Blood Loss.

Table 3
Odds of biochemical leak or clinically relevant postoperative pancreatic fistula in patients undergoing pancreaticoduodenectomy.

Variable	Univariable OR (95% CI)	P value	Multivariable OR (95% CI)	P value
Age (per year)	0.99 (0.97–1.01)	0.36		
Male Sex	1.31 (0.80–2.16)	0.29		
ASA 3/4	0.78 (0.45–1.35)	0.37		
EBL (per liter)	1.15 (0.99–1.34)	0.07	1.27 (1.08–1.49)	0.005
Intraoperative Crystalloid Given (per liter)	1.03 (0.98–1.09)	0.21		
Operative Duration (per hour)	0.98 (0.88–1.09)	0.65		
Pasireotide Administered	1.15 (0.57–2.29)	0.70		
Duct Size (per mm)	0.73 (0.62–0.86)	<0.001	0.81 (0.69–0.96)	0.01
Soft Gland	6.86 (3.18–14.8)	<0.001	4.63 (1.99–10.80)	<0.001
PDAC or Chronic Pancreatitis	0.30 (0.18–0.50)	<0.001	0.39 (0.22–0.70)	0.001
Minimally Invasive	1.23 (0.48–3.16)	0.68		
Vascular Reconstruction	0.53 (0.27–1.04)	0.06	*	
Neoadjuvant Chemotherapy	0.69 (0.36–1.29)	0.24		
Closed Suction Drainage	0.80 (0.33–1.94)	0.63	0.76 (0.28–2.05)	0.59

*Removed during single backwards elimination.
Abbreviations: OR=Odds Ratio; CI=Confidence Interval; ASA = American Society of Anesthesiologists; PDAC=Pancreatic Ductal Adenocarcinoma; EBL = Estimated Blood Loss.

the standards set forth within the Helsinki Declaration.

3. Results

3.1. Clinicopathologic characteristics

Six-hundred-twenty-nine patients undergoing pancreatic resection during the study period were identified; 41 (6.5%) patients received gravity drainage and 588 (93.5%) patients received closed suction drainage. (Table 1). There was a similar number of male to female patients in the study group (313 and 316 respectively) and the median age was 65 (IQR 16). Ninety-one percent (n = 573) of patients were White (non-Hispanic). Distribution among BMI and ASA class were similar between study groups, as was gland texture. Patients in the CSD group had a median EBL of 600 mL, while the GD group had a median EBL of 350 mL. Pasireotide administration was more common in the gravity drainage group. Whipple (pancreaticoduodenectomy) was the most common operation (n = 497, 63.1%) and was observed more in the gravity drainage group.

Between patients receiving CSD and gravity drainage, there were no significant differences in length of stay, duration of postoperative drainage, or highest drain amylase values on postoperative day 3 or 4 (Table 1). Operative time was longer for patients who received gravity drains, as was volume of crystalloid administered intraoperatively concordantly. Whipple was more common in the GD group. Length of drainage and highest POD3-4 drain amylase level did not vary with drainage method.

3.2. Odds of crPOPF

There were 59 instances of crPOPF (Table 2). On univariable analysis, factors significantly associated with increased odds of crPOPF were male sex, EBL, intra-operative crystalloid volume and soft gland texture noted at the time of resection. Surgical indication of PDAC or chronic pancreatitis was associated with a decreased rate of crPOPF on univariable analysis. Importantly, univariable analysis did not demonstrate a statistically significant relationship between CSD and crPOPF; this remained true on multivariable analysis.

On multivariable analysis, EBL was the only variable that remained associated with a significant increase in crPOPF. Conversely, indication for surgery of PDAC/chronic pancreatitis was associated with lower odds of crPOPF. Closed-suction drainage did not meet the threshold for statistical significance but was included in the final multivariable model; no meaningful correlation with crPOPF was seen with CSD in multivariable models. All other variables with univariable $P < 0.2$ were eliminated from the final models following single backward elimination.

3.3. Odds of biochemical leak or crPOPF

There were 152 instances of biochemical leak or crPOPF (Table 3) in our study group. On univariable analysis, pancreaticoduodenectomy was associated with lower odds of biochemical leak/crPOPF (OR 0.54, 95% CI 0.37–0.78, $P < 0.001$). As such, we evaluated this outcome in patients only undergoing pancreaticoduodenectomy as there were insufficient patients undergoing gravity drainage in the distal pancreatectomy group for stable modeling, given the difference in this outcome by operation type.

On univariable analysis, soft gland texture was the only variable independently associated with increased odds of biochemical leak or

Table 4
Odds of percutaneous drainage in patients undergoing pancreatectomy.

Variable	Univariable OR (95% CI)	P value	Multivariable OR (95% CI)	P value
Age (per year)	0.98 (0.97–1.00)	0.08	*	
Male Sex	1.91 (1.17–3.13)	0.01	1.66 (0.99–2.78)	0.05
ASA 3/4	1.19 (0.70–2.02)	0.53		
Whipple	0.85 (0.52–1.38)	0.51		
EBL (per liter)	1.33 (1.15–1.54)	<0.001	1.28 (1.09–1.51)	0.003
Intraoperative Crystalloid Given (per liter)	1.09 (1.04–1.14)	<0.001	*	
Operative Duration (per hour)	1.12 (1.04–1.21)	0.004	1.09 (0.98–1.20)	0.11
Pasireotide Administered	1.45 (0.76–2.76)	0.27		
Duct Size (per mm)	0.94 (0.83–1.08)	0.39		
Soft Gland	1.85 (0.91–3.75)	0.09	2.08 (0.96–4.49)	0.06
PDAC or Chronic Pancreatitis	0.69 (0.42–1.12)	0.13	0.57 (0.32–0.99)	0.049
Minimally Invasive	0.62 (0.31–1.25)	0.18	*	
Vascular Reconstruction	1.33 (0.73–2.41)	0.35		
Neoadjuvant Chemotherapy	0.90 (0.50–1.61)	0.71		
Closed Suction Drainage	0.66 (0.28–1.54)	0.33	0.70 (0.28–1.74)	0.45

*Removed during single backwards elimination.
Abbreviations: OR=Odds Ratio; CI=Confidence Interval; ASA = American Society of Anesthesiologists; PDAC=Pancreatic Ductal Adenocarcinoma; EBL = Estimated Blood Loss.

crPOPF in patients undergoing pancreaticoduodenectomy. Larger duct diameter and PDAC/chronic pancreatitis histology were both associated with significantly decreased odds of these outcomes. These associations remained true on multivariable modeling. Again, CSDs were not associated with increased odds of biochemical leak of crPOPF in either univariable or multivariable models.

3.4. Odds of percutaneous drainage

There were 77 patients requiring postoperative percutaneous drainage following pancreatectomy in our study group. On univariable analysis, need for percutaneous drainage was associated with male sex, EBL, intra-operative crystalloid, and surgical duration (Table 4). On multivariable analysis, percutaneous drainage remained associated with both male sex and EBL. Importantly, there was no meaningful association observed between percutaneous drainage and CSD in either model.

4. Discussion

Routine drain placement during pancreatectomy with early removal is a favored practice by some surgeons, though practices remain variable and conflicting dogma persists. The risks and benefits of various drainage methods are less clear, with some clinicians believing that CSDs increase the risk of POPF formation through intra-abdominal negative pressure. Using NSQIP procedure targeted pancreatectomy data supplemented with additional relevant end points, we demonstrate that CSD placement is not associated with increased biochemical leak, POPF, crPOPF, or need for percutaneous drainage at our high-volume center. Furthermore, the length of drainage or highest POD3-4 drain amylase did not change with drain type. Median EBL, a known risk factor for POPF, was 171% greater in the CSD group when compared to the GD group.

Regarding drain care, variation in the personal preferences of patients, nurses, and providers exists: CSD may allow for easier patient mobility given their gravity-independent positioning, while gravity drainage bags may be easier for some patients and nurses to empty without spillage. In the absence of data suggesting benefit or harm with either drainage method, we encourage clinicians to tailor drainage method to the situation, taking into account nursing staff and patient preferences while inpatient and outpatient, respectively.

This study is limited by small cohort size and by the volume of gravity drains placed at our center. Importantly, only one surgeon at the institution of study placed gravity drains preferentially, leading to a strong bias in the data-set towards suction-drainage. The patients in the gravity drainage group had longer operations, were more likely to receive pasireotide, and were more likely to undergo pancreaticoduodenectomy with soft gland texture noted at the time of surgery. Conversely, patients that had closed suction drains placed had increased EBL compared to patients with gravity drains, which is a known risk factor for crPOPF. Due to our cohort size, we were unable to separately analyze patients undergoing distal pancreatectomy, which may have affected the results. It is also likely that there was co-linearity among some of the variables, such as firm gland texture and PDAC/chronic pancreatitis histology, which may have interpreted our results. Notably, both gland texture and histology are established independent risk factors for POPF; it is therefore unlikely that co-linearity affected this study's finding. Additionally, in our cohort the type of operation performed was not associated with odds of percutaneous drainage or crPOPF on univariable analysis. Other variables such as gland texture, PDAC/chronic pancreatitis histology, and EBL have been reported as risk factors for POPF in both pancreaticoduodenectomy and distal pancreatectomy, and were more statistically relevant than operation type in the present study.[17,18] Furthermore, there are known interactions between PDAC/chronic pancreatitis and gland texture, though these were included as separate data points in POPF risk scores.[18] Finally, we did observe increased rates of percutaneous drain placement in male patients, although the reasons for this are unclear. This finding is consistent with existing literature which identifies increased risk of SSI, including organ space infection, in male patients.[19]

In conclusion, in the present study drainage method did not seem to be associated with POPF-related outcomes following pancreatectomy. Method of drainage should take into account the preferences of surgeon and hospital staff, as well as patient preferences if discharging with a drain for ease of care. Further studies are needed to determine whether drain type affects post-operatively mobility or drain efficacy, especially if patients are discharged with drains in place. Given that the available data, including our analysis, do not support drainage method as a risk factor for POPF, future interventional studies should focus on emerging methods to reduce the incidence of POPF, such as botulinum-toxin injection, mesh placement, and Pasireotide administration.[20–22]

Declaration of competing interest

There are no conflicts of interest or financial ties to disclose.

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