Population-Based Assessment of Selective Drain Placement During Pancreatoduodenectomy Using the Modified Fistula Risk Score

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Dimitrios Xourafas, MD, MPH, MBA, Aslam Ejaz, MD, MPH, Allan Tsung, MD, FACS,
Mary Dillhoff, MD, MS, FACS, Timothy M Pawlik, MD, MPH, MTS, PhD, FACS, Jordan M Cloyd, MD

BACKGROUND: Recent studies on postoperative pancreatic fistula (POPF) prevention suggest that omission of perioperative drains is safe for negligible- or low-risk patients undergoing pancreatoduodenectomy (PD). However, this proposed pathway has not been validated in a nationwide cohort.

STUDY DESIGN: The ACS-NSQIP—targeted pancreatectomy database from 2014 to 2016 was queried to identify patients who underwent PD. Using a previously validated modified Fistula Risk Score (mFRS), patients were stratified as negligible/low- or intermediate/high-risk. Multivariate regression models were used to analyze the effect of intraoperative drain placement on relevant perioperative outcomes in both high- and low-risk patients.

RESULTS: Among 6,730 patients undergoing PD, 3,375 (50%) were high-risk; 3,355 (50%) were low-risk. Among high-risk patients, drain placement (n = 3,093, 92%) was associated with a higher rate of POPF (26% vs 16%, $p = 0.0003$), clinically relevant (CR) POPF (20% vs 12%, $p = 0.0015$), and extended hospital length of stay (LOS, 9 vs 7 days, $p < 0.0001$), but decreased serious morbidity (29% vs 35%, $p = 0.0330$). Similarly, drain placement in low-risk patients (n = 2,785, 83%) was associated with a higher rate of POPF (11% vs 6%, $p = 0.0006$) and extended LOS (8 vs 7 days, $p < 0.0001$), yet lower serious morbidity (18% vs 23%, $p = 0.0037$). On multivariate logistic regression, drain placement was associated with significantly increased odds of CR-POPF and a significantly reduced incidence of serious morbidity among both high-risk (odds ratio [OR] 0.72, 95% CI 0.55 to 0.94, $p = 0.0155$) and low-risk patients (OR 0.71, 95% CI 0.57 to 0.89, $p = 0.0027$).

CONCLUSIONS: In this population-based cohort, the mFRS was unable to stratify patients relative to the need for selective drain placement during PD. For both high- and low-risk patients, perioperative drain placement was associated with increased rates of POPF, CR-POPF, and extended LOS, but decreased incidence of serious morbidity. (J Am Coll Surg 2019;228:583—594. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

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From the Department of Surgery, The Ohio State University Wexner Medical Center, Columbus, OH.

Correspondence address: Jordan M Cloyd, MD, Division of Surgical Oncology, The Ohio State University Wexner Medical Center, 410 W 10th Ave, N-907 Doan Hall, Columbus, OH 43210. email: jordan.cloyd@osumc.edu

Postoperative pancreatic fistula (POPF) is one of the most common and morbid complications after pancreatoduodenectomy (PD).[1-3] In fact, despite significant improvements in patient selection, centralization of cases, minimally invasive approaches, and perioperative care, rates of POPF have remained relatively stable over the past few decades.[4] Historically, routine placement of surgical drains at the time of PD has been considered mandatory in order to monitor for and potentially manage POPF. Nevertheless, because the majority of patients do not develop a POPF after PD, investigators have debated whether routine drainage is necessary or potentially

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Abbreviations and Acronyms

ASA	= American Society of Anesthesiologists
CR-POPF	= clinically relevant postoperative pancreatic fistula
LOS	= length of stay
mFRS	= modified Fistula Risk Score
OR	= odds ratio
PD	= pancreatoduodenectomy
RCT	= randomized controlled trial
SSI	= surgical site infection

subjects patients to the risks of drain-related morbidity such as postoperative infection or even erosion of pancreatic anastomoses.[5-7]

Over the last decade, numerous studies have been conducted to clarify the role of routine intra-abdominal drain placement during PD.[5,8-10] Unfortunately, the results of randomized controlled trials (RCT) have been highly contradictory. Conlon and colleagues[5] performed the first single-center RCT and found no difference in postoperative morbidity between patients who did and did not have drains placed. On the other hand, Van Buren and associates[8] performed a multicenter RCT demonstrating worse postoperative outcomes after PD, including a significantly higher rate of mortality in patients without surgical drains. Most recently, Witzigmann and coworkers[9] undertook a dual-institution RCT, which demonstrated a higher rate of clinically relevant postoperative pancreatic fistula (CR-POPF) in patients who had drains. Given the improved awareness of specific risk factors for POPF, some investigators have proposed selective drain placement in patients at high risk for development of POPF as an alternative to routine drain placement. For example, the Fistula Risk Score (FRS) is a validated instrument based on 5 peri- and intraoperative variables that have been shown to accurately stratify patients into 4 groups based on their POPF risk: negligible, low, intermediate, and high.[4,11] Using the FRS, investigators have proposed a risk-adjusted clinical care pathway in which surgical drains are omitted for negligible or low risk patients and removed early in moderate-high risk patients with low postoperative drain amylase levels.[12,13] Subsequently, a prospective multicenter trial validated this selective drain placement pathway.[14]

Despite the development of a selective drain management pathway and evidence suggesting the safety of omitting perioperative drains in low-risk patients, most surgeons continue to routinely use drains during PD, which may be related to lack of validation outside high volume centers or because of previous conflicting evidence from large RCTs.[9,14-16] Therefore, we set out to validate the previously proposed risk-stratified selective drain clinical care pathway using a nationwide cohort. Specifically, we hypothesized that the modified Fistula Risk Score (mFRS) appropriately stratified patients into a high-risk group, in which intraoperative drain placement is appropriate, and a low-risk group, in which drain placement is unnecessary.

METHODS

Data acquisition and study population

The ACS-NSQIP is a multi-institutional, prospective database that comprises preoperative, intraoperative, and 30-day postoperative variables from randomly sampled patients undergoing surgery at 600 eligible hospitals across the United States. The method of data collection implemented by the ACS-NSQIP is standardized, resulting in validated data displaying strong reliability.[17] A retrospective review of the 2014 to 2016 ACS-NSQIP and targeted pancreatectomy ACS-NSQIP databases was performed. All adult patients who underwent a PD for any indication as the index operation were identified using CPT codes 48150 and 48153. Patients were matched between the ACS-NSQIP and targeted pancreatectomy ACS-NSQIP databases based on case identification number. Patients were stratified according to their risk of POPF based on the previously validated mFRS.[18] The mFRS uses 5 significant predictors of POPF to assign points based on odds ratios for fistula occurrence: sex, BMI, preoperative total bilirubin, pancreatic ductal diameter (<3, 3 to 6, >6 mm), and gland texture (soft, intermediate, or hard). Risk scores of 0 to 2 (negligible), 3 to 6 (low), 7 to 8 (intermediate), and 9 to 10 (high) were calculated and assigned to all patients included in this study. For the purposes of this study, patients were classified as either low- (mFRS 0 to 6) or high-risk (mFRS 7 to 10). Any patients with missing data regarding POPF or drain management were excluded from the final analysis.

Study variables and outcomes

Independent variables analyzed included demographics, preoperative health status, relevant comorbidities, clinicopathologic variables, and postoperative outcomes. Demographics consisted of age and sex. Variables related to preoperative health included the American Society of Anesthesiologists (ASA) classification, BMI, weight loss (10% of total body weight in 6 months), smoking, chronic corticosteroid use, preoperative sepsis (systemic inflammatory response syndrome or septic shock), and preoperative transfusion. Targeted pancreatectomy variables included neoadjuvant therapy (chemotherapy or radiation) within 90 days before surgery and preoperative jaundice.

Comorbidities included diabetes mellitus, COPD, hypertension requiring medications, and bleeding disorder. Clinicopathologic and operative variables retrieved from the targeted pancreatectomy ACS-NSQIP database were operative approach (open, laparoscopic, or robotic), operative time in minutes (OpTime), histology subtype (benign vs malignant), and T and N stages of disease.

Postoperative outcomes included any POPF, CR-POPF, overall and serious morbidity, as well as failure to rescue from serious morbidity. Based on NSQIP definitions, POPF was defined as either a persistent drain output of amylase-rich fluid in combination with a drain longer than 7 days, percutaneous drainage, or reoperation, or as a clinical diagnosis and drain longer than 7 days, spontaneous wound drainage, percutaneous drainage, or reoperation.[19] Clinically relevant postoperative pancreatic fistula was defined as the presence of fistula in addition to a drain in place longer than 21 days, a hospital length of stay of at least 14 days, organ/space surgical site infection, postoperative percutaneous drain placement, reoperation, sepsis, shock, or single/multisystem organ failure. Specific postoperative complications measured included the following outcomes occurring within 30 days from surgery: superficial, deep, or organ/space surgical site infection (SSI), sepsis, pneumonia, thromboembolism (pulmonary embolism, deep vein thrombosis), myocardial infarction, cardiac arrest, renal complications (progressive renal insufficiency, urinary tract infection), or hemorrhage defined as bleeding requiring transfusion of at least 4 U of packed red blood cells within 72 hours from surgery. Failure to rescue was calculated as the ratio of deaths among patients with serious complications.[20] Serious morbidity included organ space SSI, cardiac arrest, pneumonia, pulmonary embolism, progressive renal insufficiency, sepsis, or reoperation. Overall morbidity included any serious morbidity as well as superficial or deep incision SSI, urinary tract infection, perioperative bleeding, deep venous thrombosis, or POPF. Perioperative mortality was defined as death within 30 days after PD. Additionally, delayed gastric emptying, hospital length of stay (LOS), discharge disposition, readmission, and reoperation were assessed.

Statistical analysis

The study was designed to evaluate the impact of intraoperative drain placement on relevant perioperative outcomes in both high- and low-FRS patients. Univariate analyses were performed to compare demographics, perioperative characteristics, and postoperative outcomes between the drain and no drain groups for both the high- and low-risk cohorts. Categorical variables were compared using chi-square or Fisher's test as appropriate; continuous variables were compared using the Wilcoxon rank sum test. Categorical variables are presented as numbers and percentages; continuous variables are presented as medians and interquartile ranges (IQR). Multivariate logistic regression analysis models were constructed to investigate the independent association of drain use with relevant perioperative endpoints (any POPF, CR-POPF, overall morbidity, serious morbidity, increased LOS, mortality, readmission, and reoperation) among both low- and high-risk patients. The multivariate models were adjusted for age, BMI, ASA class, preoperative radiation therapy, pancreatic duct size, pancreatic gland texture, and preoperative total bilirubin levels. Results are reported as odds ratios (OR) and 95% confidence intervals. All analyses were performed using SAS 9.2 (SAS Institute, Inc). A value of $p < 0.05$ was considered statistically significant.

RESULTS

Study cohort

Among 6,730 patients undergoing PD, 3,375 (50%) were classified as high-risk; 3,355 (50%) were deemed low-risk according to the mFRS (Fig. 1). The rate of perioperative drain use was 87% across the entire cohort.

High modified Fistula Risk Score patients

Among the 3,375 high-risk patients who underwent PD, 3,093 (92%) had a drain placed during PD, while 282 (8%) did not. Table 1 reports the clinicopathologic and operative characteristics of the high-risk patients who underwent PD with or without drainage. Although the median mFRS was higher among patients who underwent drain placement (8 vs 7, $p < 0.0001$), the 2 groups did not differ with regard to age (65 vs 65 years, $p = 0.8470$), ASA class ≥ 3 (70% vs 75%, $p = 0.1526$),

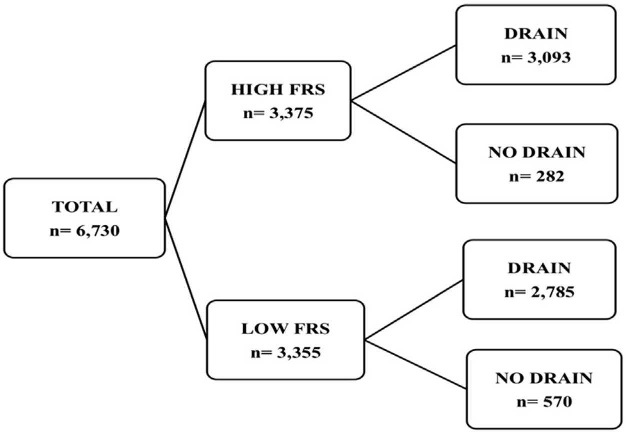

Figure 1. Flow chart of patients undergoing pancreatoduodenectomy included in the study. FRS, Fistula Risk Score.

Table 1. Demographic, Clinicopathologic, and Operative Characteristics of 3,375 Patients with High Fistula Risk Score Stratified by Drain Placement

Variable	Drain (n = 3,093)	No drain (n = 282)	p Value
Fistula Risk Score, n (range)	8 (7–10)	7 (7–10)	<0.0001*
Median total bilirubin < 2 mg/dL, n (%)	2,705 (87)	257 (91)	0.0711
Soft pancreatic gland texture, n (%)	2,310 (75)	176 (63)	<0.0001*
Pancreatic duct size, n (%)			<0.0001*
<3 mm	1,615 (52)	106 (38)	
3–6 mm	1,478 (48)	176 (62)	
Male, n (%)	2,167 (70)	199 (70)	0.8590
BMI, kg/m^2, n (IQR)	27.9 (26–32)	28 (25–32)	0.9443
Demographic			
Age, y, (IQR)	65 (56–72)	65 (56–72)	0.8470
Preoperative health status			
ASA ≥ 3, n (%)	2,164 (70)	213 (75)	0.1526
Preoperative weight loss, n (%)	414 (13)	37 (13)	0.9006
Smoker, n (%)	559 (18)	56 (20)	0.4572
Steroid use, n (%)	94 (3)	7 (2)	0.5993
Preoperative transfusion, n (%)	22 (1)	4 (1)	0.1935
Preoperative sepsis, n (%)	28 (1)	3 (1)	0.7893
Preoperative jaundice, n (%)	11 (0.3)	2 (0.7)	0.3048
Preoperative chemotherapy, n (%)	491 (16)	43 (15)	0.7291
Preoperative radiation therapy, n (%)	183 (6)	8 (3)	0.0790
Comorbidity			
Hypertension, n (%)	1,713 (55)	154 (55)	0.8026
Diabetes mellitus, n (%)	748 (24)	70 (25)	0.8105
COPD, n (%)	139 (4)	7 (5)	0.1119
Bleeding disorder, n (%)	84 (3)	6 (2)	0.5573
Clinicopathologic			
Open approach, n (%)	2,788 (90)	278 (98)	<0.0001*
Operative time, min (IQR)	367 (294–451)	326 (202–408)	<0.0001*
Malignant histology, n (%)	2,331 (75)	217 (77)	0.5532
T stage ≥ 3, n (%)	1,530 (50)	150 (53)	0.2311
N positive, n (%)	1,278 (41)	112 (40)	0.6006

*$p < 0.05$.
ASA, American Society of Anesthesiologists.

receipt of preoperative chemotherapy (16% vs 15%, p = 0.7291), radiation therapy (6% vs 3%, p = 0.0790), malignant histology subtype (75% vs 77%, p = 0.5532), T stage ≥ 3 (50% vs 53%, p = 0.2311), or lymph node positivity (41% vs 40%, p = 0.6006), (Table 1).

Postoperative outcomes for the high-risk patients who underwent PD with or without drainage are reported in Table 2. Drain placement was associated with a higher rate of POPF (26% vs 16%, p = 0.0003), CR-POPF (20% vs 12%, p = 0.0015), and extended LOS (9 vs 7 days, p < 0.0001), but significantly decreased serious morbidity (29% vs 35%, p = 0.0330). Specifically, patients who had a drain placed during PD experienced lower rates of organ/space SSI (19% vs 25%, p = 0.0214), pneumonia (3% vs 7%, p = 0.0008), renal insufficiency (0.7% vs 2.4%, p = 0.0020), sepsis (3% vs 7%, p = 0.0005), and reoperation (5% vs 9%, p = 0.0097) than patients who did not have a drain. Mortality (2% vs 3%, p = 0.2841) and readmission rates (19% vs 22%, p = 0.2217) did not differ between the 2 treatment groups.

Low modified Fistula Risk Score patients

Among the 3,355 low-risk patients who underwent PD, 2,785 (83%) had an intraoperative drain placed; 570 (17%) did not. Table 3 describes the clinicopathologic and operative characteristics of the low-risk patients who underwent PD with or without drainage. Median FRS

Table 2. Postoperative Outcomes of 3,375 Patients with High Fistula Risk Score Stratified by Drain Placement

Variable	Drain (n = 3,093)	No drain (n = 282)	p Value
Outcome			
Any POPF, n (%)	807 (26)	46 (16)	0.0003*
Clinically relevant POPF, n (%)	613 (20)	34 (12)	0.0015*
Overall morbidity, n (%)	1,633 (53)	126 (45)	0.0090*
Serious morbidity, n (%)	909 (29)	100 (35)	0.0330*
Failure to rescue, n (%)	45 (1.4)	7 (2.4)	0.1799
Readmission, n (%)	577 (19)	61 (22)	0.2217
Hospital length of stay, d, n (IQR)	9 (7−14)	7 (6−13)	<0.0001*
Discharged home, n (%)	2,635 (85)	248 (88)	0.1959
Reoperation, n (%)	169 (5)	26 (9)	0.0097*
Mortality, n (%)	59 (2)	8 (3)	0.2841
Specific complication, n (%)			
Superficial SSI	260 (8)	20 (7)	0.4438
Deep SSI	62 (2)	8 (3)	0.3478
Organ/space SSI	592 (19)	70 (25)	0.0214*
Pneumonia	93 (3)	19 (7)	0.0008*
Pulmonary embolism	46 (0.5)	4 (0.5)	0.9271
Renal insufficiency	22 (0.7)	7 (2.4)	0.0020*
Urinary tract infection	80 (2.5)	10 (3.5)	0.3383
Cardiac arrest	32 (1)	5 (2)	0.2543
Myocardial infarction	31 (1)	5 (2)	0.2277
Perioperative bleeding	474 (15)	26 (9)	0.0057*
Deep vein thrombosis	84 (3)	6 (2)	0.5573
Sepsis	97 (3)	20 (7)	0.0005*
Delayed gastric emptying	621 (20)	52 (19)	0.5678

*$p < 0.05$.
POPF, postoperative pancreatic fistula; SSI, surgical site infection.

was 5 vs 4 for patients who had a drain vs those who did not, respectively ($p = 0.0010$). However, the 2 groups did not differ with regard to age (67 vs 67 years, $p = 0.8087$), ASA class ≥ 3 (71% vs 76%, $p = 0.1662$), receipt of preoperative chemotherapy (21% vs 21%, $p = 0.7142$), malignant histology subtype (84% vs 85%, $p = 0.5380$), T stage ≥ 3 (67% vs 71%, $p = 0.0684$), or N positive stage of disease (55% vs 57%, $p = 0.2001$).

Postoperative outcomes of the low-risk patients undergoing PD with or without drainage are reported in Table 4. Drain placement in low-risk patients was associated with higher rates of POPF (11% vs 6%, $p = 0.0006$) and extended LOS (8 vs 7 days, $p < 0.0001$), yet lower serious morbidity (18% vs 23%, $p = 0.0037$). Specifically, post-pancreatectomy patients with a drain experienced significantly lower rates of organ/space SSI (8% vs 11%, $p = 0.0144$), pneumonia (2.5% vs 4.5%, $p = 0.0075$), and cardiac arrest (0.6% vs 2%, $p = 0.0012$) than those who did not receive an intraoperative drain. Mortality (2% vs 2%, $p = 0.7496$) and readmission rates (14% vs 14%, $p = 0.7212$) did not differ between the 2 groups.

Multivariate analysis: impact of drain placement during pancreatoduodenectomy

The impact of drain placement on various postoperative outcomes after controlling for confounding factors among both high- and low-risk patients is reported in Table 5. Among high- risk patients, drain placement was associated with significantly increased odds of POPF (OR 1.71, 95% CI 1.22 to 2.39, $p = 0.0017$), CR-POPF (OR 1.72, 95% CI 1.18 to 2.51, $p = 0.0046$), but a reduced incidence of serious morbidity (OR 0.72, 95% CI 0.55 to 0.94, $p = 0.0155$). Similarly, among the low-risk patients, drain placement was associated with increased odds of POPF (OR 1.88, 95% CI 1.29 to 2.73, $p = 0.0009$), CR-POPF (OR 1.53, 95% CI 1.02 to 2.29, $p = 0.0356$), but a decreased incidence of serious morbidity (OR 0.71, 95% CI 0.57 to 0.89, $p = 0.0027$). Drain placement during PD was independently associated with increased odds of a longer hospitalization for both mFRS groups, but decreased odds of reoperation for the high-risk patients only (OR 0.53, 95% CI 0.34 to 0.83, $p = 0.0060$).

Table 3. Demographic, Clinicopathologic, and Operative Characteristics of 3,355 Patients with Low Fistula Risk Score Stratified by Drain Placement

Variable	Drain (n = 2,785)	No drain (n = 570)	p Value
Fistula Risk Score, n (range)	5 (0–6)	4 (0–6)	0.0010*
Median total bilirubin < 2 mg/dL, n (%)	1,972 (71)	415 (73)	0.3612
Hard pancreatic gland texture, n (%)	1,801 (64)	327 (57)	<0.0001*
Pancreatic duct size, n (%)			<0.0001*
<3 mm	285 (10)	26 (4)	
3–6 mm	1,648 (59)	341 (60)	
>6 mm	825 (31)	201 (36)	
Male, n (%)	1,006 (36)	227 (39)	0.0948
BMI, kg/m^2, n (IQR)	24.6 (22–29)	24.3 (22–27)	0.0724
Demographic			
Age, y, (IQR)	67 (59–74)	67 (59–74)	0.8087
Preoperative health status			
ASA ≥ 3, n (%)	1,984 (71)	433 (76)	0.1662
Preoperative weight loss, n (%)	606 (22)	105 (18)	0.0756
Smoker, n (%)	548 (20)	105 (18)	0.4902
Steroid use, n (%)	62 (2)	9 (1.5)	0.3280
Preoperative transfusion, n (%)	24 (1)	4 (1)	0.7020
Preoperative sepsis, n (%)	27 (1)	6 (1)	0.8546
Preoperative jaundice, n (%)	1,460 (52)	317 (55)	0.1667
Preoperative chemotherapy, n (%)	578 (21)	121 (21)	0.7142
Preoperative radiation therapy, n (%)	287 (10)	36 (6)	0.0085*
Comorbidity			
Hypertension, n (%)	1,463 (53)	283 (50)	0.2095
Diabetes mellitus, n (%)	691(25)	160 (28)	0.1033
COPD, n (%)	122 (4)	19 (3)	0.2562
Bleeding disorder, n (%)	70 (3)	9 (1.5)	0.1801
Clinicopathologic			
Open approach, n (%)	2,556 (92)	558 (98)	<0.0001*
Operative time, min (IQR)	357 (283–448)	290 (192–395)	<0.0001*
Malignant histology, n (%)	2,351 (84)	487 (85)	0.5380
T stage ≥ 3, n (%)	1,874 (67)	406 (71)	0.0684
N positive, n (%)	1,521 (55)	328 (57)	0.2001

*$p < 0.05$.
ASA, American Society of Anesthesiologists.

DISCUSSION

Surgical drain placement at the time of PD remains controversial because RCTs have not convincingly established whether routine drain placement vs omission is the optimal approach.[5-7,10,12,14,21,22] Alternatively, a recently introduced risk-stratified strategy for selective drain placement has been put forth to eliminate the need for unnecessary drain placement in negligible- or low-risk patients, but maintain their use in moderate- and high-risk patients, which might allow for early identification and management of CR-POPF.[12,14,18] We set out to validate this clinical pathway using a population-based cohort. We found that the mFRS was unable to appropriately stratify patients relative to the need for selective drain placement during PD. Alternatively stated, the impact of drain placement on perioperative outcomes, namely, increased rates of POPF, CR-POPF, and extended LOS, but decreased incidence of serious morbidity, was consistent across both high- and low-risk patients. These findings highlight the value of surgical drains, irrespective of the FRS, in ensuring prompt recognition and early treatment of POPF.

Some surgeons have argued against routine drain placement during PD, suggesting that drains fail to reduce either the need for subsequent percutaneous drainage or reoperation for intra-abdominal sepsis. Additionally, drains

Table 4. Postoperative Outcomes among 3,355 Patients with Low Fistula Risk Score Stratified by Drain Placement

Variable	Drain (n = 2,785)	No drain (n = 570)	p Value
Outcome			
Any POPF, n (%)	297 (11)	34 (6)	0.0006*
Clinically relevant POPF, n (%)	208 (7)	30 (5)	0.0727
Overall morbidity, n (%)	1,203 (43)	219 (38)	0.0356*
Serious morbidity, n (%)	504 (18)	133 (23)	0.0037*
Failure to rescue, n (%)	38 (1.3)	12 (2.1)	0.1835
Readmission, n (%)	402 (14)	79 (14)	0.7212
Hospital length of stay, d, n (IQR)	8 (7−12)	7 (5−10)	<0.0001*
Discharged home, n (%)	2,363 (85)	514 (90)	0.0018*
Reoperation, n (%)	121 (4)	27 (5)	0.6779
Mortality, n (%)	53 (2)	12 (2)	0.7496
Specific complication, n (%)			
Superficial SSI	208 (7)	55 (10)	0.0776
Deep SSI	40 (1.4)	10 (1.7)	0.5679
Organ/space SSI	229 (8)	65 (11)	0.0144*
Pneumonia	70 (2.5)	26 (4.5)	0.0075*
Pulmonary embolism	24 (1)	7 (1)	0.4050
Renal insufficiency	16 (0.5)	5 (0.8)	0.4038
Urinary tract infection	87 (3)	10 (2)	0.0754
Cardiac arrest	19 (0.6)	12 (2)	0.0012*
Myocardial infarction	22 (1)	4 (1)	0.8268
Perioperative bleeding	601 (22)	65 (11)	<0.0001*
Deep vein thrombosis	65 (2)	19 (3)	0.1641
Sepsis	53 (2)	13 (2)	0.5542
Delayed gastric emptying	390 (14)	55 (10)	0.0055*

*$p < 0.05$.
POPF, postoperative pancreatic fistula; SSI, surgical site infection.

placed at the time of PD have been found to be associated with longer hospitalization, higher grade morbidity, fistula, and readmission rates without altering mortality rates, largely consistent with the findings of this study.[5,7,10] These findings may be especially relevant for patients at low risk of developing a POPF. This argument is further supported by growing evidence that drains are not helpful in other gastrointestinal operations.[23-26] In contrast, after pancreatectomy, drains can be used for the early detection and prompt management of POPF. Indeed, some have theorized that the worse outcomes observed in the multicenter RCT performed by Van Buren and colleagues[8] may have

Table 5. Independent Association of Drain Use with Postoperative Outcomes Based on Fistula Risk Score

	High Fistula Risk Score			Low Fistula Risk Score		
Variable	Odds ratio	95% CI	p Value	Odds ratio	95% CI	p Value
Any POPF	1.71	1.22−2.39	0.0017*	1.88	1.29−2.73	0.0009*
CR-POPF	1.72	1.18−2.51	0.0046*	1.53	1.02−2.29	0.0356*
Overall morbidity	1.30	1.01−1.68	0.0351*	1.17	0.96−1.41	0.1020
Serious morbidity	0.72	0.55−0.94	0.0155*	0.71	0.57−0.89	0.0027*
LOS > 8 days	1.53	1.18−1.97	0.0010*	1.51	1.24−1.82	<0.0001*
Mortality	0.61	0.28−1.32	0.2181	0.87	0.45−1.67	0.6815
30-day readmission	0.82	0.60−1.11	0.2091	1.01	0.77−1.31	0.9337
Reoperation	0.53	0.34−0.83	0.0060*	0.87	0.56−1.35	0.5521

The multivariate logistic regression models are constructed while controlling for age, BMI, ASA class, preoperative radiation therapy, pancreatic duct size, pancreatic gland texture, and preoperative total bilirubin levels.
*$p < 0.05$.
LOS, hospital length of stay; POPF, postoperative pancreatic fistula.

occurred because of delayed identification of POPF and a failure to rescue. Indeed, in that RCT, the mortality rate among patients with CR-POPF was 22.2% in those with a drain vs 42.9% in those without a drain.[12]

These theoretic advantages and disadvantages of drain placement during PD as well as the conflicting evidence from RCTs has resulted in wide variations in drain management among surgeons across the world. In fact, a recent global survey found that 59.2% of pancreatic surgeons always place intraoperative drains, while 26.9% of surgeons drain selectively.[27] Given the potential devastating morbidity associated with the development of POPF and the variability in fistula rates experienced across institutions, standardization of perioperative protocols could potentially lead to significant quality improvement. A selective drain placement protocol based on an objectively measured FRS has appeal for standardizing clinical care pathways and optimizing postoperative outcomes. Indeed, a recent multicenter prospective trial demonstrated that a risk-stratified management protocol was associated with significantly reduced rates of severe complications, any complications, reoperation, percutaneous drainage, and extended hospital LOS compared with historical controls. In addition, no CR-POPFs occurred in the one-quarter of patients deemed negligible/low risk by the FRS and had drains omitted.[14]

This study found that the impact of drain placement on perioperative outcomes was consistent across both high- and low-risk patients; therefore the mFRS failed to stratify patients according to the value of drain placement. In both groups, drain placement was associated with increased rate of CR-POPF but less serious morbidity; the only difference was that naturally high-risk patients experienced higher rates of both, compared with low-risk patients. This suggests that although surgical drains may be associated with a slightly higher rate of POPF and even CR-POPF, their presence may lead to earlier identification and management of pancreatic fistula, preventing serious complications or even need for reoperation (eg in the high-risk group). Because this nationwide assessment includes PDs from a variety of high and low volume hospitals across the country, the ability to rescue patients from a POPF is particularly important. Although it would be interesting to stratify this analysis based on hospital and surgeon volume, unfortunately, that information is not available in the ACS-NSQIP database. So this study does not resolve the question of whether drains should be routinely placed. However, our findings do highlight the value that monitoring of the pancreatic anastomosis provides, irrespective of fistula risk, at least across a nationwide cohort. This monitoring can be enhanced with the use of early drain amylase, which is predictive of POPF development.[28] A large body of evidence now suggests that early drain removal in those patients with low postoperative drain amylases leads to fewer CR-POPFs.[28,29] Whether routine drain placement with early removal provides the optimal balance of minimizing drain duration but allowing for anastomotic monitoring in all patients deserves further investigation.

The main limitation of this study is its retrospective, nonrandomized design, which may allow for measured and unmeasured differences to exist between the FRS groups that could potentially bias the outcomes. For example, are surgeons or hospitals that cared for patients who did not have drains placed inherently different? Were there other technical or clinical factors not reflected in the mFRS that influenced the decision to leave a drain? In addition, the ACS-NSQIP targeted pancreatectomy database does not contain all requisite variables to calculate the FRS. Therefore, a previously validated mFRS was used.[18] Despite these limitations, the strengths of this study are its multi-institutional design, large sample size, and population-based cohort reflecting everyday surgical practice.

CONCLUSIONS

In this population-based cohort study of 6,730 patients undergoing PD in the ACS-NSQIP targeted pancreatectomy database, we found that the mFRS was unable to stratify patients relative to the need for selective drain placement during PD. For both high- and low-risk patients, perioperative drain placement was associated with increased rates of POPF, CR-POPF, and extended LOS, but decreased incidence of serious morbidity. Although further multicenter prospective trials are needed to clarify optimal drain management procedures, the results of this study suggest that the value of drain placement, and early monitoring for pancreatic leak, is consistent across all risk-stratified patients.

Author Contributions

Study conception and design: Xourafas, Dillhoff, Pawlik, Cloyd

Acquisition of data: Xourafas, Cloyd

Analysis and interpretation of data: Xourafas, Ejaz, Tsung, Dillhoff, Pawlik, Cloyd

Drafting of manuscript: Xourafas, Cloyd

Critical revision: Xourafas, Ejaz, Tsung, Dillhoff, Pawlik, Cloyd

REFERENCES

1. Gouma DJ, van Geenen RC, van Gulik TM, et al. Rates of complications and death after pancreaticoduodenectomy: risk

factors and the impact of hospital volume. Ann Surg 2000;232:786e795.
2. Muscari F, Suc B, Kirzin S, et al. Risk factors for mortality and intraabdominal complications after pancreatoduodenectomy: multivariate analysis in 300 patients. Surgery 2006;139:591e598.
3. Vollmer CM Jr, Sanchez N, Gondek S, et al. The Pancreatic Surgery Mortality Study Group. A root-cause analysis of mortality following major pancreatectomy. J Gastrointest Surg 2012;16:89e103.
4. Callery MP, Pratt WB, Kent TS, et al. A prospectively validated clinical risk score accurately predicts pancreatic fistula after pancreatoduodenectomy. J Am Coll Surg 2013;216:1—14.
5. Conlon KC, Labow D, Leung D, et al. Prospective randomized clinical trial of the value of intraperitoneal drainage after pancreatic resection. Ann Surg 2001;234:487—493; discussion 493—494.
6. Fisher WE, Hodges SE, Silberfein EJ, et al. Pancreatic resection without routine intraperitoneal drainage. HPB (Oxford) 2011;13:503—510.
7. Correa-Gallego C, Brennan MF, D'Angelica M, et al. Operative drainage following pancreatic resection: analysis of 1122 patients resected over 5 years at a single institution. Ann Surg 2013;258:1051—1058.
8. Van Buren G 2nd, Bloomston M, Hughes SJ, et al. A randomized prospective multicenter trial of pancreaticoduodenectomy with and without routine intraperitoneal drainage. Ann Surg 2014;259:605—612.
9. Witzigmann H, Diener MK, Kienkötter S, et al. No need for routine drainage after pancreatic head resection: The Dual-Center, Randomized, Controlled PANDRA Trial (ISRCTN04937707). Ann Surg 2016;264:528—537.
10. Van der Wilt AA, Coolsen MM, De Hingh IH, et al. To drain or not to drain: a cumulative meta-analysis of the use of routine abdominal drains after pancreatic resection. HPB (Oxford) 2013;15:337—344.
11. Miller B, Christein J, Behrman S, et al. A multi-institutional external validation of the fistula risk score for pancreatoduodenectomy. J Gastrointest Surg 2014;18:172—179.
12. McMillan M, Fisher W, Van Buren G, et al. The value of drains as a fistula mitigation strategy for pancreatoduodenectomy: Something for everyone? Results of a randomized prospective multi-institutional study. J Gastrointest Surg 2015;19:21—30.
13. McMillan M, Malleo G, Bassi C, et al. Drain management after pancreatoduodenectomy: reappraisal of a prospective randomized trial using risk stratification. J Am Coll Surg 2015;221:798—809.
14. McMillan MT, Malleo G, Bassi C, et al. Multicenter, prospective trial of selective drain management for pancreatoduodenectomy using risk stratification. Ann Surg 2017;265:1209—1218.
15. El Khoury R, Kabir C, Maker VK, et al. Do drains contribute to pancreatic fistulae? Analysis of over 5000 pancreatectomy patients. J Gastrointest Surg 2018;22:1007—1015.
16. McMillan M, Malleo G, Bassi C, et al. Pancreatic fistula risk for pancreatoduodenectomy: An international survey of surgeon perception. HPB (Oxford) 2017;19:515—524.
17. Henderson WG, Daley J. Design and statistical methodology of the National Surgical Quality Improvement Program: why is it what it is? Am J Surg 2009;198[suppl 5]:S19—S27.
18. Kantor O, Talamonti MS, Pitt HA, et al. Using the NSQIP pancreatic demonstration project to derive a modified fistula risk score for preoperative risk stratification in patients undergoing pancreaticoduodenectomy. J Am Coll Surg 2017;224:816—825.
19. American College of Surgeons National Surgical Quality Improvement Program. User Guide for the ACS NSQIP Participant Use Data File (PUF). October 2015. Available at: https://www.facs.org/quality-programs/acs-nsqip/participant-use. Accessed January 8, 2019.
20. Ferraris VA, Bolanos M, Martin JT, et al. Identification of patients with postoperative complications who are at risk for failure to rescue. JAMA Surg 2014;149:1103—1108.
21. McMillan MT, Soi S, Asbun HJ. Risk-adjusted outcomes of clinically relevant pancreatic fistula following pancreatoduodenectomy: a model for performance evaluation. Ann Surg 2016;264:344—352.
22. Mehta VV, Fisher SB, Maithel SK, et al. Is it time to abandon routine operative drain use? A single institution assessment of 709 consecutive pancreaticoduodenectomies. J Am Coll Surg 2013;216:635—642; discussion 642—644.
23. Gurusamy KS, Samraj K, Mullerat P, Davidson BR. Routine abdominal drainage for uncomplicated laparoscopic cholecystectomy. Cochrane Database Syst Rev 2007;[4]:CD006004.
24. Karliczek A, Jesus EC, Matos D, et al. Drainage or nondrainage in elective colorectal anastomosis: a systematic review and meta-analysis. Colorectal Dis 2006;8:259—265.
25. de Rougemont O, Dutkowski P, Weber M, Clavien PA. Abdominal drains in liver transplantation: useful tool or useless dogma? A matched case—control study. Liver Transpl 2009;15:96—101.
26. Aldameh A, McCall J, Koea L. Is routine placement of surgical drains necessary after elective hepatectomy? Results from a single institution. J Gastrointest Surg 2005;9:667—671.
27. McMillan M, Malleo G, Bassi C, et al. Defining the practice of pancreatoduodenectomy around the world. HPB 2015;17:1145—1154.
28. Beane J, House M, Ceppa E, et al. Variation in drain management after pancreatoduodenectomy: early versus delayed removal. Ann Surg 2017 Oct 23 [Epub ahead of print].
29. Bassi C, Molinari E, Malleo G, et al. Early versus late drain removal after standard pancreatic resections: Results of a prospective randomized trial. Ann Surg 2010;252:207—214.

Discussion

DR SYED AHMAD (Cincinnati, OH): Based on advances that have occurred in the last several decades, pancreaticoduodenectomy can now be performed with an operative mortality rate of 3% to 5%. Despite the low mortality, morbidity remains high, most often related to the "Achilles' Heel" of the operation; that is, development of postoperative pancreatic fistulas.

Mitigating strategies to prevent postoperative pancreatic fistulas, including pharmacologic prophylaxis with somatostatin analogues, indwelling stents, and alterations of operative techniques, have demonstrated varying and controversial results. The use of intra-abdominal drains to identify and control pancreatic leaks has also