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ORIGINAL SCIENTIFIC REPORT

Prophylactic Pancreatectomies Carry Prohibitive Mortality at Low-Volume Centers: A California Cancer Registry Study

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Abstract

Background Pancreatectomy for malignancy is associated with improved outcomes when performed at high-volume centers. The goal of this study was to assess pancreatectomy outcomes for premalignant cystic lesions as a function of hospital volume.

Methods The Healthcare Cost and Utilization Project (HCUP) was queried for all pancreatectomies performed in California from 2003 to 2011. Cases were stratified, separating benign versus malignant disease. Hospitals were categorized as low-volume (≤25 pancreatectomies/year; LV) or high-volume (>25; HV) centers. Perioperative morbidity, mortality, and length of stay were compared in HV vs. LV centers.

Results There were 7554 pancreatectomies performed in 201 hospitals during the study period, where 5652 (75%) procedures were performed for malignancy, 338 (4%) for chronic pancreatitis, and 1564 (21%) for benign/premalignant cysts. The majority of pancreatectomies for cystic disease were performed at LV centers (65%). There were no significant differences in length of stay (7 vs. 8 days; $p = 0.6$) or 90-day readmission rates (12.8% vs. 12.9%; $p = 1.0$) in HV versus LV centers. However, there were higher surgical (46.2% LV vs. 41.1% HV, $p = 0.05$) and medical (13.3% LV vs. 9.2% HV; $p = 0.017$) complications at LV centers. Most importantly, there was a fourfold higher in-hospital mortality at LV centers (2.36% vs. 0.55%; $p = 0.007$).

Conclusion Pancreatic resection for benign lesions at HV hospitals is associated with significantly lower morbidity and mortality, suggesting that when feasible, patients should seek care at high-volume centers for these semi-elective surgeries.

Introduction

The incidental identification and surgical resection of benign pancreatic neoplasms, including intraductal papillary mucinous neoplasm (IPMN), mucinous cystic neoplasm (MCN), and serous cystic neoplasm (SCN), are increasing with the expanded use of cross-sectional imaging [1]. The prevalence of these pancreatic cysts in asymptomatic individuals is approximately 2.5% and reported to be as high as 10% in persons age 70 or older [2]. IPMN has a 20% risk of carcinoma in situ and a 45% risk of invasive carcinoma, while MCN has approximately a 17.5% chance of malignant transformation [2]. Given the

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risk of malignancy, diagnosis of these premalignant lesions presents a therapeutic challenge as to whether observation or surgical intervention is more appropriate. Despite the inherent risk of pancreatic resection, patients are frequently offered distal pancreatectomy, pancreatoduodenectomy, or total pancreatectomy based on size or imaging criteria as per consensus guidelines [1].

Previous studies have demonstrated an improvement in both the rates of morbidity and mortality when pancreatic resection for malignancy was performed at a high-volume (HV) institution (defined as >25 index cases/year) [3–9]. From the late 1990s to 2000s major cancer operations such as pancreatectomies became more concentrated in certain centers [10]. Furthermore, Schmidt et al. noted a significant improvement in outcomes associated with pancreaticoduodenectomy when performed at a center with increased volume [10]. These and other studies have demonstrated not only a decrease in the most common complications associated with pancreatectomy, such as fistula, delayed gastric emptying, and surgical site infection, but also an association with more prolonged patient survival [11].

The relationship between complication rates following prophylactic pancreatectomy for benign disease and surgical volume of the institution where they are performed has yet to be established. The International Study Group of Pancreatic Fistula has defined a grading system for postoperative pancreatic fistula and has identified risk factors for clinically relevant postoperative pancreatic fistula [12]. These include factors often seen in patients who present with benign disease without chronic pancreatitis, including soft pancreatic parenchyma and a small duct [13]. Therefore, patients with benign or premalignant lesions treated with pancreaticoduodenectomy may be more likely to develop organ space infection and sepsis [14]. Postoperative pancreatic fistula can precipitate bleeding, sepsis, and subsequent mortality, and is thus considered the most troublesome complication after pancreatic surgery.

The present study hypothesized that differences in morbidity and mortality following pancreatectomy for benign disease would correlate with hospital volume.

Methods

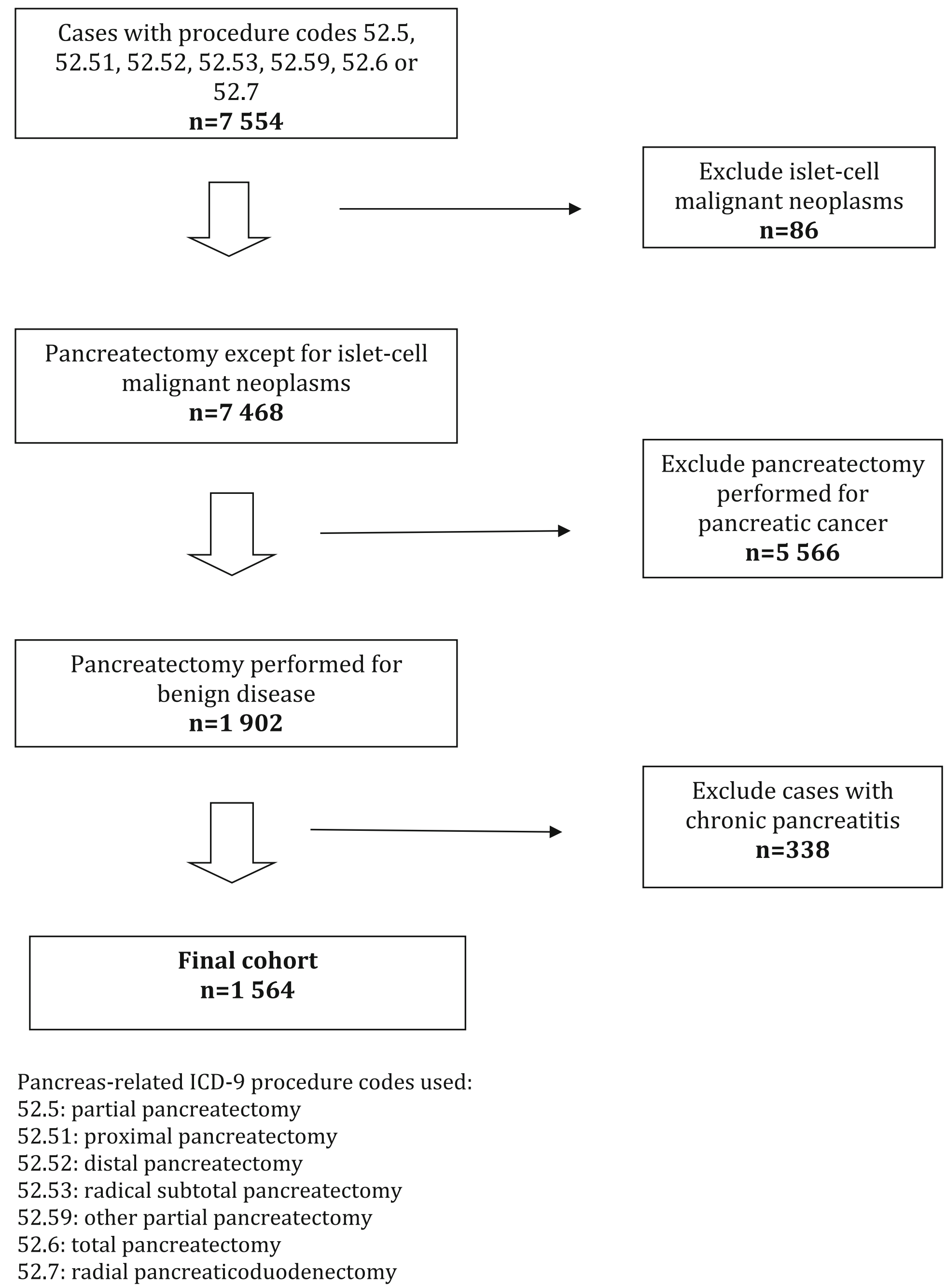
Data were acquired from the Healthcare Cost and Utilization Project (HCUP) for California state inpatient databases (SID) for the years 2003 to 2011, which were the most recent years available at the time of study initiation. The SID databases use ICD-9-CM coding for diagnoses and procedures, and include principal diagnosis and procedure, plus as many as 24 additional diagnosis codes or 20 other procedure codes for each discharge record. Data in the SID are de-identified, although California is one of only eight states and the largest by population for which revisit variables are available through HCUP. Access to revisit data enables analysis of 30-day and 90-day postsurgical admissions for patients potentially readmitted for complications. Use of the ICD-9 codes for diagnosis and treatment enables assessment of comorbid conditions present on admission and the occurrence of any surgical or medical complications during hospitalization. The SID data sets also include information on length of stay (LOS) and status at discharge, including death. HCUP data sets apply the American Hospital Association standard for identifying hospitals with two or more separate facilities as a single hospital, and permit analysis of the number of pancreatic resections reported at each hospital by year [15].

Cases were selected if they included codes for distal pancreatectomy, (ICD-9 codes 52.5, 52.52, 52.59), pancreaticoduodenectomy (ICD-9 codes 52.51, 52.53, 52.7), or total pancreatectomy (ICD-9 code 51.6). Any records associated with one of these procedures was also required to have a corresponding ICD-9 principal diagnosis code, or one of the 24 other diagnosis variables that included codes for pancreatic cysts (211.6, 577.2), pancreatic cancer (157.0–157.9), or for malignant islet cell tumors (157.4).

Hospital volume was calculated by averaging the annual number of procedures for each hospital. Hospitals were divided into two groups: low volume (≤25 cases/year, LV) or high volume (>25 cases/year, HV). An average of 25 cases per year was selected based on prior research on hospital volume and resection of visceral malignancy [8]. After sorting hospitals into groups by volume, a subset of patients with a principal diagnosis of benign pancreatic disease was selected as the study cohort (Fig. 1). Patients with a diagnosis of chronic pancreatitis were excluded from data analysis as this condition causes hardening of the gland, a clinical scenario more closely related to the desmoplastic reaction found with pancreatic cancer. In eliminating patients with chronic pancreatitis, we focused the analysis on patients with pancreatic cysts and premalignant lesions.

Complications specific to pancreatic surgery were identified by using ICD-9 diagnosis or procedure codes associated with pancreatic fistula, delayed gastric emptying, gastrointestinal obstruction, dumping syndrome, peritoneal abscess, anastomotic or bile leak, hemorrhage associated with procedure; respiratory infection, edema, or insufficiency associated with procedure; wound-related; or cerebrovascular accidents. Medical complications were identified by using codes associated with sepsis, renal failure, anesthesia-related, myocardial infarction or shock, urinary tract infection, peripheral vascular complications, deep vein thrombosis, or pulmonary embolism. A dichotomous variable indicating the absence or presence of

Fig. 1 Flowchart of patients who underwent pancreatic resections (n = 7554). Patients were excluded for islet cell neoplasms (n = 73), pancreatic cancer (n = 5566), and chronic pancreatitis (n = 338). The final cohort of patients had pancreatectomy performed for benign disease (n = 1564)



one or more of these complications was created to evaluate complication risk by hospital volume.

Variables for patient age, gender, race, and health insurance status (Medicaid, Medicare, private or HMO, other, or missing) were created. Comorbidity was measured using the Deyo modification of the Charlson Comorbidity Index (CCI) [16], and grouped into three levels representing none, one, or more than one condition. A dichotomous variable was created to distinguish teaching from non-teaching hospitals. Hospitals with National Cancer Institute-designated Cancer Center status were also identified.

All statistical analyses were conducted using Stata/MP 13.1 (StataCorp LP, College Station, TX). Unless otherwise indicated, all tests were two-tailed with alpha of $p < 0.05$ for indicating statistical significance. To identify predictors of in-hospital mortality or complications, we applied stepwise multivariable logistic regression with backward elimination and a selection criterion of $p \leq 0.10$

Table 1 Demographics by hospital volume among patients with pancreatic cysts (n = 1564)

Group	Hospital volume		p value
	Low volume (n = 1019)	High volume (n = 545)	
Age, mean (SD)	57.0 (16.2)	57.5 (15.6)	0.56
Gender			<0.001[a]
Female (%)	709 (69.6)	350 (64.2)	
Male (%)	296 (29.0)	163 (29.9)	
Unknown (%)	14 (1.4)	32 (5.9)	
Race			<0.001[b]
Asian/PI	116 (11.4)	73 (13.4)	
Black	61 (6.0)	26 (4.8)	
Hispanic	234 (23.0)	53 (9.7)	
Other	13 (1.3)	12 (2.2)	
White	547 (53.7)	336 (61.7)	
Unknown	48 (4.7)	45 (8.3)	
Health insurance			0.006[c]
Medicaid/self-pay	102 (10.0)	39 (7.2)	
Medicare	356 (34.9)	188 (34.5)	
Private/HMO	516 (50.6)	308 (56.5)	
Other	45 (4.4)	10 (1.8)	
Comorbidity status			0.035
None	619 (60.8)	367 (67.3)	
One	306 (30.0)	138 (25.3)	
≥Two	94 (9.2)	40 (7.3)	
NCI hospital status			<0.001
Non-NCI	938 (92.0)	126 (23.1)	
NCI	81 (8.0)	419 (76.9)	
Teaching hospital status			<0.001
No	891 (87.4)	0 (0)	
Yes	128 (12.6)	545 (100.0)	
Type of surgery			0.674
Distal Pancreatectomy	783 (76.8)	353 (64.8)	
Pancreaticoduodenectomy	210 (20.6)	182 (33.4)	
Total Pancreatectomy	26 (2.6)	10 (1.8)	

[a] p value for gender was calculated based on known data for male and female, excluding unknown value

[b] p value for race was calculated based on known data for Black, Hispanic, White and Asian/Pacific Islander, excluding unknown/other values

[c] p value for health insurance was calculated based on known data for Medicaid/indigent, Medicare and Private Insurance, excluding other value

to remain in the model. The Hosmer–Lemeshow goodness-of-fit method was applied to evaluate model specification (LOS represents counted data that starts with the value of 1, and is positively skewed). Therefore, a zero-truncated negative binomial (ZTNB) regression was used to model the impact of hospital volume and other predictors on LOS after determining that this statistic provided a better fit to the data compared with other models for count data [17]. As in the logistic regression models, variables in the LOS model were selected by applying stepwise regression with backward elimination.

Results

Demographic results

A final cohort of 1564 patients was selected for analysis. The demographic data of this patient population are presented in Table 1. The average patient age did not differ between LV and HV centers (57.0 vs. 57.5 years, p = 0.6). There were predominantly female patients treated with pancreatectomy for benign pancreatic disease, and this did not differ between LV and HV centers (69.6% vs. 64.2%,

$p = 0.38$). A greater proportion of Black and Hispanic patients were more likely to be treated at LV centers, whereas a greater proportion of White and Asian/Pacific Islander patients were more likely to undergo pancreatectomy at a HV center ($p < 0.001$).

More patients had private insurance/HMO at HV than LV centers (56.5% vs. 50.6%; $p = 0.006$). Patients with a greater proportion of comorbidities were treated at LV centers (≥2 comorbidities, 9.2% at LV vs. 7.3% at HV centers, $p = 0.04$), while healthier patients were more likely to be treated at HV centers (60.8% at LV vs. 67.3% at HV with no comorbidities, $p = 0.04$). In terms of the specific hospitals in which pancreatectomy was performed, the majority of HV centers were NCI-designated hospitals (76.9% HV vs. 8.0% LV, $p < 0.001$), and all HV centers were teaching hospitals (100% HV vs. 12.6% LV, $p < 0.001$). According to the cutoff of 25 cases per year, we identified 68 hospitals in the LV group and 4 hospitals in the HV group.

Types of pancreatic surgery

The type of pancreatic surgery performed is detailed in Table 1. The majority of pancreatic cysts surgery performed in both LV and HV centers was distal pancreatectomy (76.8%, 783/1019 LV vs. 64.8%, 353/545 HV). Pancreaticoduodenectomy was the next most common surgery performed, comprising 20.6% (210/1019) of cases performed at LV centers, and 33.4% (182/545) performed at HV centers. There was no significant difference in type of pancreatic surgery performed between LV and HV centers.

Surgical outcomes

Data regarding complications, length of stay, and mortality are listed in Table 2. There was a trend toward significance in the number of surgical complications observed in LV vs. HV centers, with 46.2% surgical complications at LV and 41.1% at HV centers ($p = 0.052$). There were significantly fewer medical complications seen at high-volume centers (9.2% HV vs. 13.3% LV, $p = 0.017$). Readmission rates at 30 days (9.0% at LV vs. 7.9% at HV, $p = 0.445$), between 31 and 90 days (6.1% at LV vs. 6.6% at HV, $p = 0.685$), or between 1 and 90 days (12.9% at LV vs. 12.8% at HV, $p = 0.995$) were not significantly different. Most importantly, mortality rate was fourfold higher at LV centers (2.4% vs. 0.55%, $p = 0.007$).

Mortality

A multivariable logistic regression model for in-hospital mortality for all patients is shown in Table 3 and then further stratified into mortality for distal pancreatectomy and pancreaticoduodenectomy in Tables 4 and 5 respectively. We eliminated total pancreatectomy from the analysis given the small number of patients in this group. Regardless of the type of surgery, all patients with ≥2

Table 2 Perioperative outcomes by hospital volume among patients with pancreatic cysts ($n = 1564$)

Group	Hospital volume		
	Low volume ($n = 1019$)	High volume ($n = 545$)	p value
In-hospital mortality	24 (2.4)	3 (0.6)	0.007
Distal pancreatectomy	12	2	0.052
Whipple	10	1	
Total	2		
Any surgical complications	471 (46.2)	224 (41.1)	
Any medical complications	135 (13.3)	50 (9.2)	0.017
Length of stay, mean (IQR)	8 (6–13)	7 (6–11)	0.56
Readmission within 30 days	92 (9.0)	4 (7.9)	0.445
Readmission between 31 and 90 days	62 (6.1)	36 (6.6)	0.685
Readmission between 1 and 90 days	131 (12.86)	70 (12.84)	0.995

Table 3 Multivariable logistic regression model for overall in-hospital mortality

Predictor	In-hospital mortality			
	Pancreatic cysts ($n = 1516$)			
	OR	95% CI LL	95% CI UL	p value
Age	1.02	0.99	1.06	0.137
Gender				
Male	1.00 (ref.)	–	–	–
Female	0.5	0.23	1.11	0.089
Comorbidity				
None	1.00 (ref.)	–	–	–
1	5.15**	1.63	16.27	0.005
≥2	13.59***	4.13	44.76	0.000
Procedure				
Distal	1.00 (ref.)	–	–	–
Whipple		0.96	5.10	0.061
Total	3.74	0.75	18.79	0.109
Hospital volume				
<25	1.00 (ref.)	–	–	–
≥25	0.21*	0.06	0.72	0.013
Constant	0.0018284	0.0002059	0.0162339	0.000

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table 4 Multivariable logistic regression model for in-hospital mortality for distal pancreatectomy

Predictor	In-hospital mortality			
	Pancreatic cysts (n = 1099)			
	OR	95% CI LL	95% CI UL	p value
Gender				
Male	1.00 (ref.)	–	–	–
Female	0.30*	0.10	0.91	0.034
Comorbidity				
None	1.00 (ref.)	–	–	–
1	6.91**	1.81	26.34	0.005
≥2	5.11	0.81	32.13	0.082
Teaching hospital				
No	1.00 (ref.)	–	–	–
Yes	3.73	0.93	14.98	0.064
Hospital volume				
<25	1.00 (ref.)	–	–	–
≥25	0.15*	0.02	0.96	0.045
Constant	0.01***	0.00	0.03	<0.001

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table 5 Multivariable logistic regression model for in-hospital mortality for pancreaticoduodenectomy

Predictor	In-hospital mortality			
	Pancreatic cysts (n = 387)			
	OR	95% CI LL	95% CI UL	p value
Race	1.39	1.00	1.95	0.052
Teaching hospital	0.05**	0.00	0.45	0.008
Comorbidity	16.16***	4.2	62.19	<0.001
Constant	0.001***	0.0001	0.02	<0.001

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

comorbidities were seen to have an increased risk of mortality (OR 13.6, 95% CI 4.13–44.76, p = 0.000) (Table 3). Neither age, gender, nor procedure was predictive of mortality. Overall, surgery at a HV center was significantly protective against mortality (OR 0.21, 95% CI 0.06–0.72, p = 0.01).

When examined specifically for distal pancreatectomy, female gender was found to be protective against mortality (OR 0.3, 95% CI 0.1–0.91, p = 0.03), as was surgery at a HV center (OR 0.15, 95% 0.02–0.96, p = 0.05). The presence of comorbidities was found to be a risk factor for mortality in distal pancreatectomy (OR 6.91, 95% CI 1.81–26.34, p = 0.005 for one comorbidity, OR 5.11, 95% CI 0.81–32.13, p = 0.082 for ≥2 comorbidities). When examining outcomes for pancreaticoduodenectomy, surgery at a teaching hospital was found to be protective (OR 0.05, 95% CI 0–045, p = 0.008), while the presence of comorbidities was found to be associated with higher mortality risk (OR 16.16, 95% CI 4.2–62.19, $p < 0.001$, Table 5).

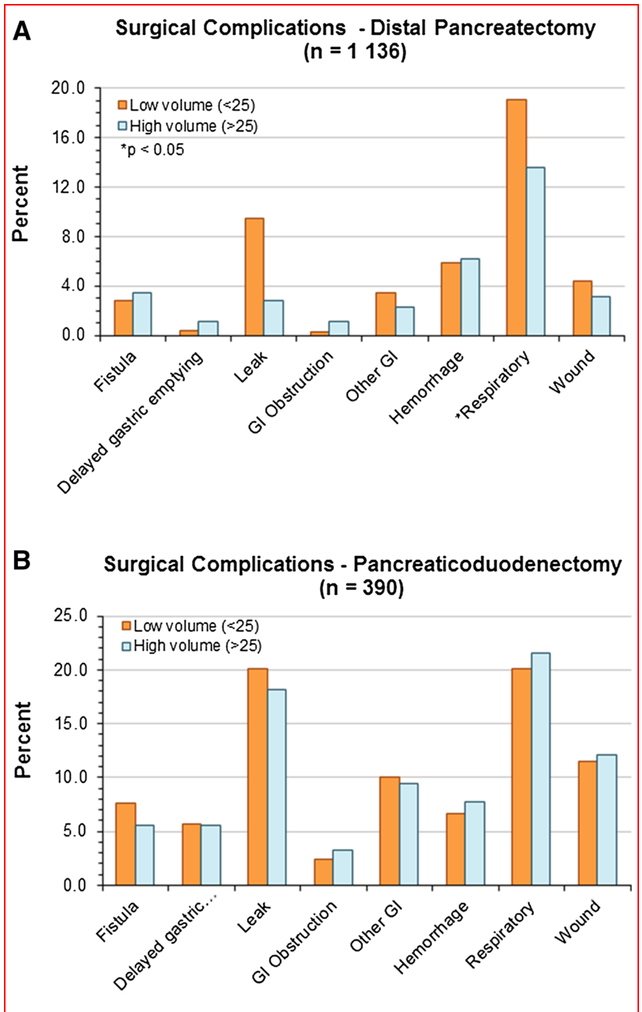


Fig. 2 Surgical complications for patients undergoing distal pancreatectomy (**a**) and pancreaticoduodenectomy (**b**) for benign lesions of the pancreas in HV (>25/year) and LV (<25/year) centers

Surgical complications

Surgical complications are further stratified by type of surgery in Fig. 2a, b, and a multivariable logistic regression model is shown for surgical complications in Table 6. For distal pancreatectomy, only respiratory complications were seen to be significantly different between LV and HV centers (19.0% vs. 13.6%, p = 0.025). Although the leak rate was 9.5% for LV and 2.8% for HV, this did not meet significance. Overall, there were no significant differences in surgical complications between LV and HV centers for pancreaticoduodenectomy. On multivariable logistic regression, female gender (OR 0.74, 95% CI 0.59–0.94,

Table 6 Multivariable logistic regression model for surgical complications

Predictor	Complications—surgical			
	Pancreatic cysts (n = 1562)			
	OR	95% CI LL	95% CI UL	p value
Gender				
Male	1.00 (ref.)	–	–	–
Female	0.74*	0.59	0.94	0.013
Unknown	0.27	0.07	1.07	0.063
Comorbidity				
None	1.00 (ref.)	–	–	–
1	1.61***	1.27	2.05	<0.001
≥2	1.86**	1.28	2.72	0.001
Race				
White	1.00 (ref.)	–	–	–
Black	0.92	0.58	1.47	0.725
Hispanic	0.84	0.63	1.12	0.244
Asian-PI	0.63*	0.45	0.9	0.010
Other	0.84	0.36	1.95	0.682
Missing	0.40*	0.19	0.83	0.014
NCI hospital				
No	1.00 (ref.)	–	–	–
Yes	0.56**	0.41	0.78	0.001
Teaching hospital				
No	1.00 (ref.)	–	–	–
Yes	1.54**	1.14	2.09	0.005
Procedure				
Distal	1.00 (ref.)	–	–	–
Whipple	1.88***	1.47	2.41	<0.001
Total	4.30***	2.09	8.88	<0.001
Constant	0.54***	0.42	0.70	<0.001

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

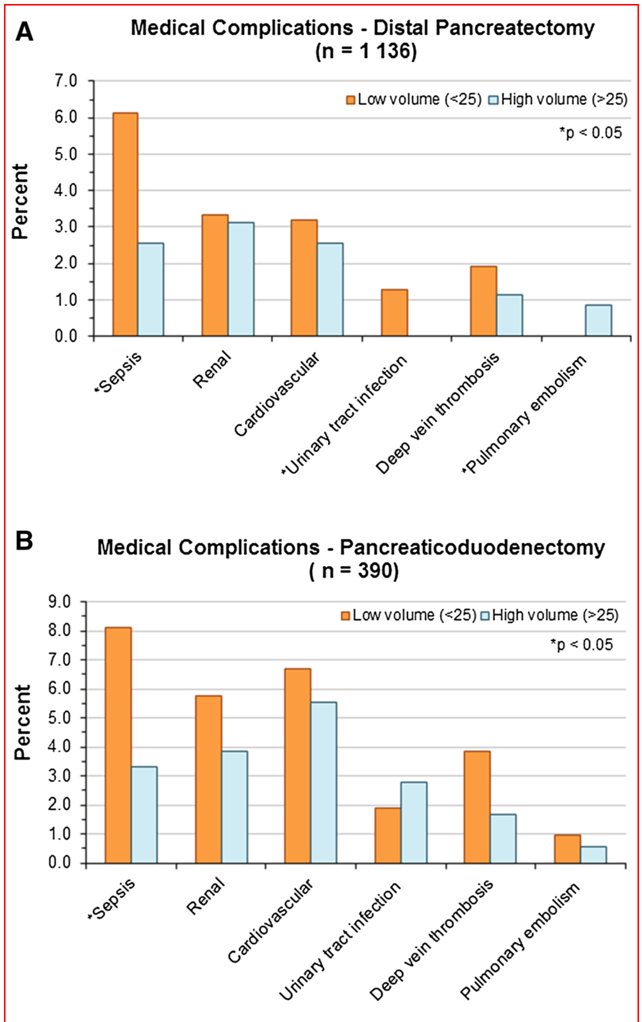


Fig. 3 Medical complications for patients undergoing distal pancreatectomy (**a**) and pancreaticoduodenectomy (**b**) for benign lesions of the pancreas in HV (>25/year) and LV (<25/year) centers

p = 0.013), Asian-Pacific Islander race (OR 0.63, CI 0.45–0.9, p = 0.01), and NCI hospital (OR 0.56, 95% CI 0.41–0.78, p = 0.001) were protective against surgical complications (Table 6). Factors predicting surgical complications included pancreatic surgery at a teaching hospital (OR 1.54, 95% CI 1.14–2.09, p = 0.005); pancreaticoduodenectomy (OR 1.88, 95% CI 1.47–2.41, $p < 0.001$); total pancreatectomy (OR 4.3, 95% CI 2.09–8.88, $p < 0.001$); having one comorbidity or more [OR 1.61, 95% CI 1.27–2.05, $p < 0.001$ (1 comorbidity), OR 1.86, 95% CI 1.28–2.72, $p < 0.001$ (≥2 comorbidities)], (Table 6).

Medical complications

Medical complications are divided by type of surgery in Fig. 3a, b, and a multivariable logistic regression model for medical complications is illustrated in Table 7. In nearly every category of complications evaluated, LV centers had an observably higher incidence of complications; however, only a few categories were statistically significant. For distal pancreatectomy, sepsis (6.13% in LV vs. 2.55% in HV, p = 0.012) and urinary tract infection (1.28% in LV vs. 0% in HV, p = 0.04) were significantly higher in LV centers, while pulmonary embolism was higher in HV centers (0% vs. 0.85%, p = 0.03). In terms of pancreaticoduodenectomy, only sepsis trended toward a difference between LV and HV centers (8.13% in LV vs. 3.31% in HV, p = 0.053).

Length of stay

The multivariable zero-truncated negative binomial regression model for LOS revealed that female gender

Table 7 Multivariable logistic regression model for medical complications

Predictor	Complications—medical			
	Pancreatic cysts (n = 1516)			
	OR	95% CI LL	95% CI UL	p value
Gender				
Male	1.00 (ref.)	–	–	–
Female	0.55***	0.40	0.76	<0.001
Unknown	–	–	–	–
Comorbidity				
None	1.00 (ref.)	–	–	–
1	2.17***	1.53	3.08	<0.001
≥2	3.82***	2.42	6.03	<0.001
Procedure				
Distal	1.00 (ref.)	–	–	–
Whipple	1.42	1.00	2.03	0.051
Total	3.37**	1.53	7.44	0.003
Hospital volume				
<25	1.00 (ref.)	–	–	–
≥25	0.69*	0.48	0.99	0.042
Constant	0.13***	0.09	0.18	<0.001

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

(IRR 0.73, 95% CI 0.66–0.79, $p < 0.001$), and Black race (IRR 0.78, 95% CI 0.65–0.93, $p = 0.007$), Hispanic race (IRR 0.88, 95% CI 0.79–0.99, $p = 0.028$), or Asian/Pacific Islander race (IRR 0.76, 95% CI 0.66–0.86, $p < 0.001$) were associated with shorter hospital stays. (Table 8) The presence of 1 (IRR 1.36, 95% CI 1.24–1.49, $p < 0.001$) or ≥2 comorbidities (IRR 1.34, 95% CI 1.16–1.55, $p < 0.001$) and both Medicare (IRR 1.17, 95% CI 1.04–1.31, $p = 0.007$) and Medicaid/Indigent insurance status (IRR 1.49, 95% CI 1.28–1.72, $p < 0.001$) were correlated with a longer hospital stay. In addition, the incidence rate ratio for length of stay at HV hospitals is 0.81 times the ratio for LV hospitals (95% CI 0.74–0.88, $p < 0.001$). In other words, stays at HV centers are 19% shorter. Both pancreaticoduodenectomy (IRR 1.59, 95% CI 1.45–1.75, $p < 0.001$) and total pancreatectomy (IRR 2.1, 95% CI 1.62–2.72, $p < 0.001$), as compared to distal pancreatectomy, were associated with longer hospital length of stay.

Discussion

The correlation between hospital volume and improved outcomes in pancreatectomy for pancreatic adenocarcinoma has been well established. Decreased morbidity, hospital length of stay, mortality, and improved overall survival have been demonstrated when procedures are performed in high-volume centers. This current study demonstrates that a high-volume center [6, 8, 10, 18] has a protective effect for mortality for benign pancreatic disease, demonstrating a fourfold increase in mortality when pancreatectomy is performed in a low-volume center. These findings have will continue to have important implications as the incidental identification of pancreatic cysts will continue to rise with the concomitant rise in cross-sectional imaging as a diagnostic modality.

The data shown herein on complications is somewhat compelling. There was a trend toward increased overall surgical complications at LV centers, but the most significant difference seen between high-volume and low-volume centers was in the frequency of sepsis in the postoperative setting in LV centers (Fig. 3b). This finding persisted regardless of the type of surgery performed. Importantly, sepsis is the factor that alone could have the highest impact on patient survival.

Two other complications that were often associated with LV centers were pancreatic fistula and anastomotic leak. Pancreatectomy for benign disease is in itself a complex surgical procedure; without the desmoplastic reaction caused by malignancy, the character of the gland is often soft and more susceptible to anastomotic leak [13, 14]. Callery et al. and Pratt et al. both include gland consistency and size of pancreatic duct in predictive scoring models for pancreatic fistula after pancreaticoduodenectomy [12, 13]. Therefore, taking the complexity of this procedure into account, both patients and healthcare practitioners could benefit from the resources offered by HV centers.

Several factors account for the discrepant outcome seen in patients treated in LV versus HV hospitals. For instance, higher-volume centers possess not only surgeons with experience in performing complex procedures but also nursing and ancillary staff accustomed to recognizing the most common complications. Interventional gastroenterologists and interventional radiologists are more often employed at higher-volume centers and are able to perform less invasive interventions such as stent or drain placement as opposed to a return to the operating room. The abundance and variety of resources found at a HV center improve the chances of rescuing a sick patient, thus preventing the mortality from sepsis. HV centers are often teaching hospitals with a residency, and this has been associated with improved postoperative mortality [19]. This concept has been studied and characterized as the high-volume cancer resection ecosystem by Kothari et al., 2016 [20]. Their work demonstrated that after overall operative volume, factors related to infrastructure, size, staffing and perioperative services and support all contributed to the ecosystem whereby when present, were associated with less mortality in complex cancer

Table 8 Multivariable zero-truncated negative binomial regression model for length of stay

Predictor	Length of Stay			
	Pancreatic Cysts (*n* = 1545)			
	IRR	95% CI LL	95% CI UL	*p* value
Age	0.99***	0.99	1.00	<0.001
Gender				
Male	1.00 (ref.)	–	–	–
Female	0.73***	0.66	0.79	<0.001
Unknown	0.60**	0.40	0.89	0.012
Comorbidity				
None	1.00 (ref.)	–	–	–
1	1.36***	1.24	1.49	<0.001
≥2	1.34***	1.16	1.55	<0.001
Race				
White	1.00 (ref.)	–	–	–
Black	0.78***	0.65	0.93	0.007
Hispanic	0.88**	0.79	0.99	0.028
Asian-PI	0.76***	0.66	0.86	<0.001
Other	1.35*	0.99	1.84	0.059
Missing	0.70***	0.55	0.89	0.004
Insurance				
Private/HMO	1.00 (ref.)	–	–	–
Medicare	1.17***	1.04	1.31	0.007
Medicaid/Self-pay	1.49***	1.28	1.72	<0.001
Other	1.41***	1.13	1.75	0.002
Hospital volume				
Low (<25)	1.00 (ref.)	–	–	–
High (≥25)	0.81***	0.74	0.88	<0.001
Commission on Cancer hospital				
No	1.00 (ref.)	–	–	–
Yes	1.13***	1.04	1.22	0.003
Procedure				
Distal	1.00 (ref.)	–	–	–
Whipple	1.59***	1.45	1.75	<0.001
Total	2.10***	1.62	2.72	<0.001
Constant	15.17***	12.51	18.40	<0.001

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

operations. Their conclusions were that in low-volume hospitals, where these factors were in place, low-mortality outcomes could be achieved. This remains an area of further investigation in order to determine whether these findings could be extended to high-risk procedures such as pancreatectomy for premalignant disease.

Additional explanations for the association between volume and outcomes in pancreatic surgery have been attributed to hospital volume serving as a surrogate for surgeon volume. Nathan et al. demonstrated that for hepatic resections, hospital procedure volume predicted mortality, but surgeon volume did not [21]. However, for pancreatic resection, both hospital and surgeon procedure volume predicted mortality. Importantly, the hospital volume effect for pancreatic resection was largely explained by surgeon volume. Therefore, at least for pancreatic resections for premalignant disease, perhaps the volume effect could be explained by high-volume surgeons practicing at these centers who are able to identify problems early and rescue their patients more efficiently.

The limitations of our study are common to population-based data, with a high number of cases and low number of variables. HCUP does not provide data that would enable to further delineate pathologic diagnosis, or to obtain clinical details that might provide a more granular analysis of complications. Specifically, there are aspects of pathology, duct size, and gland texture that significantly contribute to perioperative complications and by extension mortality that are not captured in this data set. Similarly, we are unable to further predict survival or long-term outcomes of our patient population based on a retrospective database review. Although we controlled for such factors in our multivariable analysis, it is interesting to note that sicker, more often uninsured patients are receiving care at low-volume centers. Future studies could look more closely at which aspects are most significant in terms of patient outcomes.

Consensus guidelines recommend resection for patients with intraductal papillary mucinous neoplasm and mucinous cystic neoplasm, based upon specific criteria including size and imaging characteristics [1]. Our study suggests that these patients will experience a fourfold protective effect if they seek surgical intervention in a high-volume center, similar to patients undergoing pancreatectomy for malignancy. As available dollars for healthcare spending decreases, regionalization of all pancreatic surgery to centers of excellence could decrease operative mortality and length of stay, thus decreasing the amount spent on individual patients. Because these are prophylactic interventions performed to prevent malignant degeneration, the morbidity and mortality associated with a low-volume center may be unacceptable to the informed patient. As we continue to strengthen the association of hospital experience and patient outcomes, these data may support certain aspects of promoting regionalization of care to centers of excellence.

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