ORIGINAL ARTICLE

Patient and Hospital Characteristics on the Variance of Perioperative Outcomes for Pancreatic Resection in the United States

A Plea for Outcome-Based and Not Volume-Based Referral Guidelines

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Hypothesis: There is an effect of patient and hospital characteristics on perioperative outcomes for pancreatic resection in the United States.

Design: Retrospective cohort study.

Setting: Academic research.

Patients: Patient data from the Nationwide Inpatient Sample of the Healthcare Cost and Utilization Project from January 1988 to January 2003.

Main Outcome Measures: In-hospital mortality, perioperative complications, and mortality following a major complication.

Results: A total of 103 222 patients underwent major pancreatic surgery. The annual number of pancreatic resections increased 15.0% during the 16-year study period. Resection for benign pancreatic disease increased 26.8%. Overall in-hospital mortality, perioperative complications, and mortality following a major complication were 6.5%, 35.6%, and 15.6%, respectively. Multivariate analysis demonstrated that significant independent predictors for these 3 perioperative outcomes were advancing age, male sex, medical comorbidity, and hospital volume for each type of pancreatic resection. The in-hospital mortality for pancreatoduodenectomy increases with age and ranges from 1.7% to 13.8% ($P < .001$). After adjusting for other confounders, the odds of in-hospital mortality for pancreatoduodenectomy, distal pancreatectomy, and total pancreatectomy in those 65 years or older were 4.78-fold, 3.84-fold, and 2.60-fold, respectively, lower in the high-volume hospitals compared with those in the lower-volume hospitals.

Conclusions: Perioperative complications derived from this population-based study were higher than those reported in many case series. A significant disparity was noted in perioperative outcomes among surgical centers across the United States. An outcome-based referral guideline may have an immediate effect on improving the quality of care in patients who undergo pancreatic resection for benign and malignant disease.

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In the United States, the annual incidence of malignant pancreatic neoplasm is estimated at 37 170 cases, with 33 370 deaths each year.[1] These numbers confirm the lethality of this disease. Pancreatic resection is necessary for cure or long-term survival. Only 10% to 20% of patients will have resectable tumors at initial presentation, and only 10% to 20% of patients who undergo resection will survive 5 years.[2]

See Invited Critique at end of article

Findings from recent studies[3-6] suggest that major pancreatic resection can be performed with an operative mortality of 5% or less. Patients who have postoperative complications are likely to have reduced quality of life and shortened long-term survival. The number of pancreatic resections has progressively increased during the last decade. This increase is multifactorial but includes increased detection of malignant and premalignant pancreatic lesions and surgeons' willingness to operate on older and higher-risk patients. With the narrow therapeutic margin of pancreatic resection, it is imperative to minimize operative mortality and postoperative complications. Even with the welcome reports of decreased perioperative mortality from major case series, perioperative complications (PCs) remain significant.[7-10] The objective of this study was to determine independent risk factors for poor perioperative outcomes from major pancreatic resections across surgical centers in the United States.

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METHODS

DESIGN AND SETTING

Cases were selected from the Nationwide Inpatient Sample of the Healthcare Cost and Utilization Project. The sample years were from January 1988 to January 2003. Cases were selected based on the *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis and procedure codes.

SELECTION CRITERIA

Inclusion

A case was included for analysis if it had any of the following diagnosis codes: 152.0, 152.4, 152.8, 152.9, 211.2, 211.6, 211.7, 577.1, 577.2, and 577.8. The procedure codes used were distal pancreatectomy (code 52.52), total pancreatectomy (code 52.6), and pancreatoduodenectomy (code 52.7).

Comorbidities identified for this study are a subset of those used by Elixhauser et al.[11] These include congestive heart failure, chronic pulmonary disease, diabetes mellitus, hypertension, obesity, renal failure, valvular disease, weight loss, and angina. The years of the study are further subdivided into 3 periods to determine if there is a temporal relationship to outcome. These terciles are 1988 to 1993 (era A), 1994 to 1998 (era B), and 1999 to 2003 (era C); this represents a 6-, 5-, and 5-year span, respectively.

Perioperative Outcomes

We defined postoperative complications based on the presence of *International Classification of Diseases, Ninth Revision, Clinical Modification*, diagnosis codes representing the following 6 categories of complications: cerebrovascular (codes 430-432, 434.00, 434.01, 434.10, 434.11, and 436), pulmonary (codes 415.1, 481-482, and 485-486), cardiovascular (codes 410 and 427), renal (code 584), lower extremity (codes 451.1, 451.19, and 451.20), and wound infection (code 998.59). The postoperative complications and in-hospital mortality (IHM) were defined as any of these events or death that occurred during the hospital stay. Mortality following a major complication (postcomplication mortality [PCM]) is defined as any death among patients who experience any of these complications.

STATISTICAL ANALYSIS

Comparisons of demographic data between eras and outcomes among resection types were made using χ^2 tests for categorical variables. Multivariate logistic regression models of IHM, PCs, and PCM were created accounting for clustering in the sample design. Categorical variables were present in the models. Results are reported as the odds ratio (95% confidence interval) relative to a reference category that is explicitly stated or, for comorbidity, is the absence of that comorbidity. *P* values are given for individual odds ratios within a variable's categories and for the variable as a whole within the model.

An alternative analysis of the effect of volume on the various outcomes that does not assume that volume has the same effect independent of age and resection type was performed. Subpopulations defined by age group and resection type were analyzed independently. For each subgroup, a logistic regression model adjusting for sex, race/ethnicity, comorbidity, malignant neoplasm, era, and categorical volume was created. Only the odds ratios for the volume groups, relative to the mean rather than to a specific volume category, are reported. Because of the small numbers, the 2 oldest age categories for total pancreatectomy (65-74 and ≥75 years) were collapsed into a single age category (≥65 years). Some volume categories within these age and resection type subgroups had no patients with the outcome; by reporting odds ratios relative to a mean effect, these cases did not preclude determining odds ratios if the volume category in question happened to be the reference category. In addition, within resection type and volume categories, a comparison across age categories was made using the Kruskal-Wallis test. Results are considered statistically significant at $P < .05$.

RESULTS

GENERAL DEMOGRAPHICS

The 16 years of Nationwide Inpatient Sample data consisted of 108 087 386 cases. Of these, 103 222 met the selection criteria for this retrospective cohort study. Overall, 49.8% of the cohort were male, and 48.9% were 65 years or older at the time of their surgery (**Table 1**). Pancreatoduodenectomy (66.5%) was the most common pancreatic surgery performed, followed by distal pancreatectomy (27.4%) and total pancreatectomy (6.1%). Malignant neoplasm (70.5%) was the main indication for pancreatic resection in this study cohort. During the study period, the number of pancreatic resections increased 36.5% from era A to era B and a further 12.1% from era B to era C. The number of major pancreatic surgical procedures for benign pancreatic disease increased 26.8% from era B to era C.

OVERALL PERIOPERATIVE OUTCOMES

Three perioperative outcomes were examined, namely, IHM, PCs, and PCM. These perioperative outcomes were statistically unchanged during 16 years (data not shown). Overall, IHM was 6.5%, PCs were 35.6%, and PCM was 15.6%. When each type of pancreatic resection was analyzed separately, distal pancreatectomy had the most favorable perioperative outcomes compared with pancreatoduodenectomy and total pancreatectomy. The respective IHM rates were 3.2%, 7.5%, and 10.2%; the respective PCs were 27.0%, 38.9%, and 37.9%; and PCM rates were 9.4%, 16.7%, and 23.2% ($P < .001$ for all).

RISK FACTORS FOR PERIOPERATIVE OUTCOMES

We next examined patient and hospital variables that might predict perioperative outcome in this cohort of patients. Multivariable analysis demonstrated that the variables consistently predicting higher overall IHM, PCs, and PCM were advancing age, male sex, medical comorbidity, type of pancreatic resection, and hospital volume (**Table 2**). The C statistic, which represents the area under the receiver operating characteristic curve for the respective model, was 0.76 for IHM, 0.65 for PCs, and 0.70 for PCM. For further subset analysis of perioperative outcomes, only variables that were associated with an odds ratio exceeding 1.5 were examined. Therefore, only age, type of pancreatic resection, and hospital volume were included in the following subset analysis.

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Table 1. Percentages of Characteristics of Patients Undergoing Pancreatic Resection in the 16-Year Study Period in the United States

Characteristic	Overall (N=103 222)	Era A 1988-1993 (n=30 247)	Era B 1994-1998 (n=34 409)	Era C 1999-2003 (n=38 566)
Age, y				
0-44	13.6	15.5	13.2	12.6
45-54	15.3	14.3	14.9	16.5
55-64	22.2	22.6	21.6	22.3
65-74	31.2	32.8	31.8	29.4
≥75	17.7	14.8	18.5	19.2
Sex				
Male	49.8	50.6	49.8	49.2
Female	50.2	49.4	50.2	50.8
Race/ethnicity				
White	81.4	84.8	82.6	78.5
Black	8.6	6.8	9.6	8.6
Other/missing	10.0	8.4	7.8	12.9
Medical comorbidity				
Congestive heart failure	3.6	3.0	4.0	3.7
Chronic obstructive pulmonary disease	9.6	6.8	9.7	11.6
Diabetes mellitus	18.5	14.8	19.2	20.7
Hypertension	24.3	11.8	24.7	33.6
Obesity	1.3	0.6	1.1	2.0
Renal insufficiency	1.0	0.7	1.0	1.2
Angina	1.0	0.8	1.4	0.7
Type of pancreatic resection				
Distal pancreatectomy	27.4	28.5	25.6	28.0
Pancreatoduodenectomy	66.5	63.4	68.8	67.0
Total pancreatectomy	6.1	8.1	5.6	4.9
Type of neoplasm				
Benign	29.5	28.9	27.8	31.5
Malignant	70.5	71.1	72.2	68.5

RELATIONSHIP BETWEEN TYPE OF RESECTION, AGE, HOSPITAL VOLUME, AND PERIOPERATIVE OUTCOMES

We subsequently examined the effect of hospital volume on each perioperative outcome for each type of pancreatic resection and age group. The tables demonstrate IHM, PCs, and PCM for pancreatoduodenectomy (**Table 3**), distal pancreatectomy (**Table 4**), and total pancreatectomy (**Table 5**).

PANCREATODUODENECTOMY

The overall IHM for pancreatoduodenectomy was 7.6%. It ranges from 1.7% in patients younger than 45 years to 8.2% in patients aged 65 to 74 years, and to 13.8% in patients 75 years or older. Within each age group, there is a wide range of IHM for each hospital category according to annual case volume. After adjusting for potential confounders for age, sex, race/ethnicity, comorbidity, and type of lesions, the incident rate of IHM correlated inversely with hospital volume for each type of pancreatic resection. The odds ratios for IHM between hospitals with annual volumes of fewer than 3 cases relative to hospitals with annual volumes of at least 36 cases were 1.39, 3.06, 6.12, 4.54, and 4.47 for age groups younger than 45, 45 to 54, 55 to 64, 65 to 74, and 75 years or older, respectively (**Figure**, A). For example, in patients 75 years or older, IHM rates were 13.0%, 15.6%, and 21.0% in hospitals with annual volumes of 6 to fewer than 12, 3 to fewer than 6, and fewer than 3 cases, respectively. The same trend was observed for PCs, which range from 26.8% in patients younger than 45 years to 48.4% in patients 75 years or older, a risk ratio of 1.80 (Table 3). The PCM is strikingly different across the age groups, being lowest (4.8%) in the age group younger than 45 years and highest (24.3%) in the age group 75 years or older, a risk ratio of 5.11. Similarly, differences in PCM are noted across various hospital volume categories and are most evident in older age groups. Figure, B and C show the adjusted odds ratios of PCs and PCM, respectively, between hospital volume groups within age groups and the 3 major types of pancreatic resections, including pancreatoduodenectomy.

DISTAL PANCREATECTOMY

The IHM, PCs, and PCM for distal pancreatectomy are higher in older patients and in hospitals with lower annual case volumes (Table 4). The overall IHM for distal pancreatectomy is 3.1%. Younger patients (<45 years) have the lowest IHM of 0.7%. Hospitals with an annual case volume of at least 24 cases consistently have IHM of less than 3.0% (range, 0.0%-2.8%), regardless of age group. However, in patients 65 years or older, hospitals with an annual case volume of fewer than 12 cases consistently have IHM exceeding 4.0% (range, 4.3%-10.6%). The PCs in older patients exceed 30.0% (31.3% and 38.3% for the age groups 65 to 74 and ≥75 years, respectively). Within these age groups, higher annual hospital case volume showed a trend of lower PCs. The overall PCM for distal pancreatectomy

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Table 2. Multivariate Analysis of Determinants of In-Hospital Mortality, Perioperative Complications, and Mortality Following a Major Complication Among the Cohort of 103 222

Variable	In-Hospital Mortality		Perioperative Complications		Mortality Following a Major Complication	
	Odds Ratio (95% CI)	*P* Value	Odds Ratio (95% CI)	*P* Value	Odds Ratio (95% CI)	*P* Value
Age, y		<.001		<.001		<.001
0-44	0.3 (0.2-0.5)	<.001	0.7 (0.7-0.8)	<.001	0.3 (0.2-0.5)	<.001
45-54	0.7 (0.6-0.9)	.009	0.9 (0.8-1.0)	.03	0.7 (0.5-0.9)	.01
55-64	1 [Reference]		1 [Reference]		1 [Reference]	
65-74	1.4 (1.2-1.6)	.001	1.4 (1.3-1.5)	<.001	1.1 (0.9-1.3)	.42
≥75	2.6 (2.1-3.1)	<.001	1.8 (1.6-1.9)	<.001	1.8 (1.5-2.1)	<.001
Sex		<.001		<.001		<.001
Female	1 [Reference]		1 [Reference]		1 [Reference]	
Male	1.4 (1.3-1.6)	<.001	1.3 (1.3-1.4)	<.001	1.4 (1.2-1.6)	<.001
Race/ethnicity		.006		.03		.02
White	1 [Reference]		1 [Reference]		1 [Reference]	
Black	1.4 (1.1-1.8)	.02	1.1 (1.0-1.3)	.08	1.3 (0.9-1.7)	.13
Other/missing	1.2 (1.0-1.4)	.01	0.9 (0.9-1.0)	.09	1.2 (1.1-1.4)	.01
Medical comorbidity						
Congestive heart failure	2.5 (2.0-3.1)	<.001	3.6 (3.0-4.2)	<.001	1.6 (1.3-2.0)	<.001
Chronic obstructive pulmonary disease	1.3 (1.0-1.5)	.01	1.3 (1.2-1.4)	<.001	1.1 (0.9-1.3)	.62
Diabetes mellitus	0.6 (0.5-0.8)	<.001	0.9 (0.8-0.9)	<.001	0.6 (0.5-0.8)	<.001
Hypertension	0.6 (0.5-0.7)	<.001	0.7 (0.7-0.8)	<.001	0.7 (0.6-0.8)	<.001
Obesity	0.5 (0.2-1.2)	.13	1.1 (0.9-1.5)	.34	0.6 (0.3-1.5)	.27
Renal insufficiency	6.3 (4.3-9.2)	<.001	2.3 (1.8-3.0)	<.001	3.5 (2.2-5.4)	<.001
Angina	1.1 (0.6-1.8)	.78	0.8 (0.6-1.1)	.21	1.1 (0.6-2.0)	.70
Type of pancreatic resection		<.001		<.001		<.001
Distal pancreatectomy	1 [Reference]		1 [Reference]		1 [Reference]	
Pancreatoduodenectomy	1.8 (1.5-2.2)	<.001	1.5 (1.4-1.6)	<.001	1.4 (1.1-1.8)	.002
Total pancreatectomy	2.9 (2.1-3.6)	<.001	1.5 (1.3-1.8)	<.001	2.6 (1.9-3.5)	<.001
Type of neoplasm		<.001		.69		.003
Benign	1 [Reference]		1 [Reference]		1 [Reference]	
Malignant	1.4 (1.2-1.8)	<.001	1.0 (0.9-1.1)	.69	1.4 (1.1-1.8)	.003
Calendar years		.08		.18		.34
1988-1993	1.2 (1.0-1.4)	.03	0.9 (0.8-1.0)	.09	1.1 (1.0-1.4)	.15
1994-1998	1.1 (0.9-1.2)	.56	1.0 (0.9-1.1)	.82	1.0 (0.9-1.2)	.62
1999-2003	1 [Reference]		1 [Reference]		1 [Reference]	
Hospital volume, cases/y		<.001		<.001		<.001
<3	4.0 (3.1-5.1)	<.001	1.7 (1.5-1.9)	<.001	2.9 (2.2-3.8)	<.001
3-5	3.0 (2.3-3.9)	<.001	1.4 (1.4-1.6)	<.001	2.3 (1.7-3.0)	<.001
6-11	2.5 (1.9-3.3)	<.001	1.4 (1.2-1.5)	<.001	2.0 (1.5-2.7)	<.001
12-23	1.7 (1.3-2.4)	<.001	1.1 (0.9-1.2)	.38	1.6 (1.1-2.2)	.007
24-35	1.2 (0.8-2.0)	.42	1.2 (1.0-1.6)	.07	1.0 (0.6-1.7)	.92
≥36	1 [Reference]		1 [Reference]		1 [Reference]	

Abbreviation: CI, confidence interval.

was 9.4%. For older patients (≥65 years), PCM in hospitals with an annual volume of fewer than 12 cases consistently exceeds 12.0% (range, 12.3%-20.1%). For these age groups, PCM in a higher-volume hospital is lower, ranging from 0.0% to 12.8%. After adjusting for potential confounders such as age, sex, race/ethnicity, comorbidity, and type of lesions, the incident rate of IHM correlated inversely with hospital volume for each type of pancreatic resection. The adjusted odds ratios for IHM, PCs, and PCM between each hospital category and age group for distal pancreatectomy are shown in the Figure.

TOTAL PANCREATECTOMY

Total pancreatectomy has the highest overall IHM, PCs, and PCM compared with other types of major pancreatic resection. These end points also proportionately affect older patients and remain high even in hospitals with the largest annual volumes. They are even higher in hospitals with lower annual hospital volumes (Table 5). After adjusting for other confounders, the odds of in-hospital mortality for pancreaticoduodenectomy, distal pancreatectomy, and total pancreatectomy in the 65 years or older age group were 4.78-, 3.84-, and 2.60-fold, respectively, lower in the high-volume hospitals compared with the lower-volume hospitals. The adjusted odds ratios for IHM, PCs, and PCM between each hospital volume and age group for total pancreatectomy are shown in the Figure.

COMMENT

The number of pancreatic resections in the United States has increased 15.0% during the last decade, with a 26.8%

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Table 3. In-Hospital Mortality, Perioperative Complications, and Mortality Following a Major Complication in Patients Who Underwent Pancreatoduodenectomy[a]

Hospital Annual Volume, Cases/y	In-Hospital Mortality Rate, %	Perioperative Complications Rate, %	Mortality Rate Following a Major Complication, %
Age <45 y (n=5392)			
All	1.69	26.84	4.76
<3	2.42	33.75	5.84
3-5	1.53	34.36	4.46
6-11	2.68	26.98	5.79
12-23	0.73	22.64	3.24
24-35	0.00	30.40	0.00
≥36	1.59	19.78	6.00
Age 45-54 y (n=9698)			
All	3.83	31.41	9.84
<3	6.93	37.86	14.00
3-5	4.98	33.31	11.00
6-11	3.52	29.85	9.50
12-23	0.95	25.00	3.77
24-35	1.93	30.23	6.38
≥36	2.12	28.51	7.43
Age 55-64 y (n=15 851)			
All	5.72	33.45	15.00
<3	10.74	41.16	23.10
3-5	7.39	34.69	17.74
6-11	4.73	34.09	12.63
12-23	1.89	27.74	5.06
24-35	1.31	30.41	4.31
≥36	1.73	25.98	6.66
Age 65-74 y (n=24 131)			
All	8.16	42.85	16.42
<3	12.61	51.76	20.92
3-5	10.48	46.01	19.60
6-11	6.48	42.92	13.40
12-23	4.72	31.91	11.32
24-35	4.35	34.57	12.60
≥36	2.64	32.85	7.26
Age ≥75 y (n=13 505)			
All	13.79	48.40	24.30
<3	21.02	55.38	31.88
3-5	15.61	47.90	26.10
6-11	12.95	48.41	24.74
12-23	8.72	43.16	18.50
24-35	6.34	40.22	13.96
≥36	4.92	42.09	10.51

[a] The overall rates were 7.6% in-hospital mortality, 38.9% perioperative complications, and 16.7% mortality following a major complication.

Table 4. In-Hospital Mortality, Perioperative Complications, and Mortality Following a Major Complication in Patients Who Underwent Distal Pancreatectomy[a]

Hospital Annual Volume, Cases/y	In-hospital Mortality Rate, %	Perioperative Complications Rate, %	Mortality Following a Major Complication
Age <45 y (n=7507)			
All	0.65	19.29	2.28
<3	0.00	18.80	0.00
3-5	1.40	20.01	3.21
6-11	1.40	20.68	6.79
12-23	0.43	19.31	0.00
24-35	0.00	18.70	0.00
≥36	0.46	17.78	2.56
Age 45-54 y (n=5172)			
All	2.11	23.94	6.46
<3	3.87	26.47	11.84
3-5	1.36	25.19	3.47
6-11	2.08	19.52	2.81
12-23	2.10	20.06	10.40
24-35	0.00	34.25	0.00
≥36	0.64	21.36	2.99
Age 55-64 y (n=5643)			
All	3.21	27.89	9.82
<3	3.18	28.86	9.27
3-5	2.21	31.92	6.94
6-11	3.76	23.70	8.58
12-23	8.60	36.30	23.69
24-35	1.33	25.80	5.15
≥36	0.00	19.78	0.00
Age 65-74 y (n=6176)			
All	3.90	31.30	11.28
<3	4.95	36.16	12.33
3-5	5.32	36.07	13.98
6-11	4.29	27.12	13.97
12-23	1.67	26.67	4.55
24-35	1.59	25.48	6.25
≥36	1.29	22.98	5.61
Age ≥75 y (n=3747)			
All	7.79	38.28	16.00
<3	9.20	40.97	17.33
3-5	7.93	34.06	18.05
6-11	10.64	41.10	20.09
12-23	6.69	42.86	12.77
24-35	2.82	23.24	0.00
≥36	2.38	34.89	6.71

[a] The overall rates were 3.1% in-hospital mortality, 27.0% perioperative complications, and 9.4% mortality following a major complication.

increase in resections for benign pancreatic disease. This trend is multifactorial and may be in part due to increased public awareness of pancreatic disease and greater use of imaging modalities.

Our study highlights that overall perioperative outcomes, especially IHM, are much higher than those reported in most case series.[3-6] We also noted significant variance in perioperative outcomes across surgical centers in the United States. During the last decade, multiple National Cancer Institute (NCI)–affiliated medical centers have reported through their case series that perioperative mortality for major pancreatic resection has been significantly reduced.[12] Our study indicates that 51.7% of all distal pancreatectomies and 46.3% of all pancreaticoduodenectomies performed in the United States during 16 years were in small-volume hospitals with fewer than 6 cases annually. Similar trends have been reported in other population-based studies.[13-16] This may explain our finding of higher-than-reported overall IHM, as well as the variance of perioperative outcomes across US centers. Therefore, the favorable outcomes published by case series from NCI-affiliated centers may not accurately reflect outcomes from other centers in the United States. The results of NCI-affiliated cancer centers should be considered a benchmark on which to base future national standards.

Systematic quality improvement programs and strategies to maintain them require a significant amount of time and resources to establish and implement. However, vol-

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Table 5. In-Hospital Mortality, Perioperative Complications, and Mortality Following a Major Complication in Patients Who Underwent Total Pancreatectomy[a]

Hospital Annual Volume, Cases/y	In-Hospital Mortality Rate, %	Perioperative Complications Rate, %	Mortality Rate Following a Major Complication, %
Age <45 y (n=1166)			
All	4.46	33.10	10.90
<3	9.69	48.52	23.17
3-5	2.96	25.44	10.63
6-11	5.17	38.79	8.89
12-23	6.48	35.63	12.50
24 to 35	0.00	25.77	0.00
≥36	0.00	25.00	0.00
Age 45-54 y (n=905)			
All	7.40	30.94	23.93
<3	9.23	31.54	29.27
3-5	0.00	15.62	0.00
6-11	9.77	28.57	34.21
12-23	8.38	43.11	19.44
24-35	6.49	25.97	25.00
≥36	7.19	33.09	21.74
Age 55-64 y (n=1381)			
All	8.04	35.28	21.50
<3	10.59	33.46	31.70
3-5	6.31	36.88	16.22
6-11	11.01	49.34	17.86
12-23	7.48	28.57	26.19
24-35	0.00	65.00	0.00
≥36	0.00	8.06	0.00
Age ≥65 y (n=2806)			
All	14.43	43.37	27.56
<3	19.78	51.14	35.50
3-5	11.57	39.17	19.00
6-11	15.02	45.27	24.10
12-23	9.61	29.18	26.83
24-35	19.35	57.26	26.76
≥36	7.61	35.20	21.58

[a]The overall rates were 10.2% in-hospital mortality, 37.9% perioperative complications, and 23.2% mortality following a major complication.

ume-based referrals for pancreatic surgery undermine local expertise and may leave patients far from supportive social networks. At best, volume is a proxy measure for complex system interactions, which require further study. Alternatively, some studies, notably the National Surgical Quality Improvement Program, have not demonstrated an association between volume and outcome.[15,16] In our opinion, an outcome-based referral guideline may have a more immediate effect. Such a guideline can overcome the uncertainties of system interactions, support local expertise and economy, and promote optimal quality of care. Low-risk patients may be well cared for at hospitals meeting a national benchmark, regardless of their volume. Higher-risk patients would be best treated at high-volume centers with focused expertise.

To assist in formulating a risk-adjusted perioperative outcomes guideline, we examined 3 major perioperative outcomes. These were IHM, PCs, and PCM. Consistently, the 3 independent predictors for these specific perioperative outcomes were patient characteristics (age and comorbidities), procedural characteristics (type of pancreatic resection), and hospital characteristics (hospital volume).

Advancing age has been repeatedly shown to be an independent predictor of perioperative outcomes.[17-26] These differences are significantly more evident in patients who have medical comorbidity that includes congestive heart failure and chronic renal insufficiency. Our data support the assertion that older patients have significantly higher PCs and PCM, as well as overall IHM. Age remains an independent prognostic factor in the multivariate analysis. The overall IHM rates for distal pancreatectomy among patients younger than 45 years and 75 years or older were 0.7% and 7.8%, respectively (unadjusted risk ratio, 11.3); the rates for pancreatoduodenectomy among the same age groups were 1.7% and 13.8%, respectively (unadjusted risk ratio, 8.1). We believe that a patient's age may be a close proxy of his or her functional performing status. Patients 65 years or older may be best served at higher-volume centers. This conclusion is supported by prior investigators.[27,28] A policy of selective referral of higher-risk patients to high-volume centers would improve outcomes and may help to reduce disparity in referral for complex surgical care.[29] Lower-risk patients could continue to receive their care in community hospitals that meet benchmarks derived from Nationwide Inpatient Sample data and subsequently from NCI-designated cancer centers.

Pancreatic surgery can be a high-risk surgical procedure. Our study demonstrates that the overall IHM for major pancreatic resection is 6.5%. This is double the risk of mortality for coronary artery bypass surgery (approximately 3%) and is 6 times the risk of mortality for hip replacement surgery (approximately 1%).[30,31] Furthermore, each type of pancreatic resection has its own technical nuances and some unique PCs. This is consistent with our findings that overall rates of IHM and PCs following total pancreatectomy for patients younger than 45 years are 4.5% and 33.1%, respectively, and those following distal pancreatectomy are 0.7% (unadjusted risk ratio, 6.4) and 19.3% (unadjusted risk ratio, 1.7). Surgical experience, technical proficiency, and perioperative care have a pivotal role in overall patient outcomes.

It is also the nature of pancreatic surgery that postoperative complications are significantly greater compared with those of other types of general surgical procedures. Therefore, it is essential to have a well-designed and established system in place to care for such patients. Building this infrastructure requires extensive institutional commitment and support. Our data demonstrate that IHM rates for pancreatoduodenectomy in lowest-volume and highest-volume centers for patients 75 years or older are 21.0% and 4.9%, respectively (unadjusted risk ratio, 4.3). The risk of PCM for major pancreatic resection follows a similar trend. High volume seems to be a proxy for centers with established quality systems having appropriate teams and processes in place to care for patients in need of pancreatic surgery.

Given our present data, we propose an outcome-driven guideline based on patient characteristics, type of pancreatic resection, and hospital volume. The IHM rates for distal pancreatectomy, pancreatoduodenectomy, and total pancreatectomy should be less than 3.0%, 7.0%, and 10.0%, respectively. We anticipate that guidelines derived from NCI-designated cancer centers would lead to

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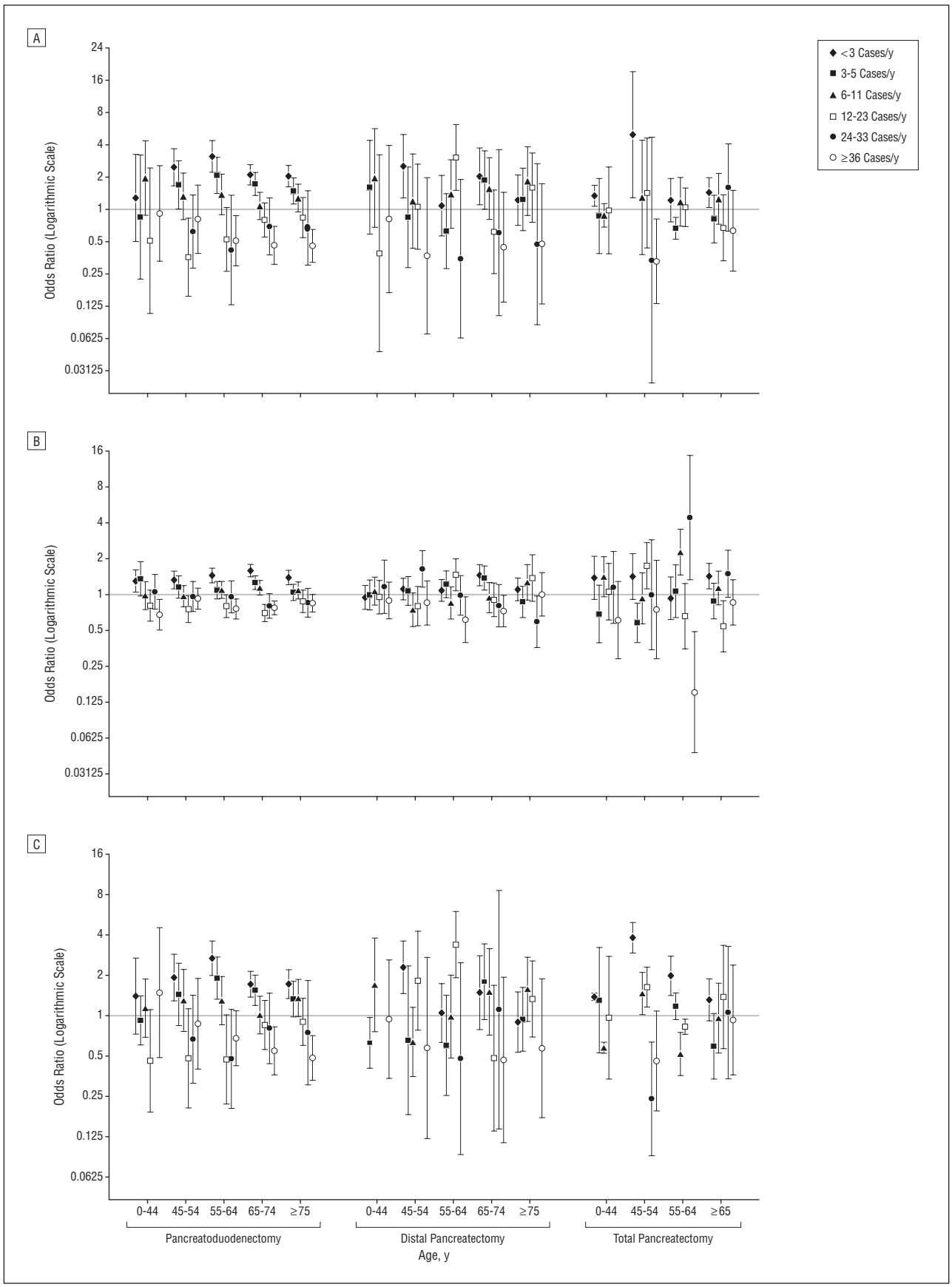

Figure. Odds ratios (with 95% confidence intervals) for in-hospital mortality (A), perioperative complications (B), and mortality following a major complication (C) in models adjusting for sex, race/ethnicity, comorbidity, malignant neoplasm, era, and categorical volume in subgroups of patients by pancreatic resection type and age group.

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lower-mortality benchmarks. We suggest that high-risk patients in need of pancreatic resection should be referred to a center with appropriate expertise and infrastructure that has an outcome equal or better than the mentioned IHM. Herein, we have shown that patients 65 years or older or with significant medical comorbidity should be regarded as high risk. Similarly, our data demonstrate that hospitals with equal or better IHM than benchmark data have a higher volume of at least 12 cases per year. By following this guideline, community hospitals could continue to perform pancreatic surgery for low-risk patients if they meet national benchmarks. Higher-risk patients would be cared for by hospitals that have appropriate focused expertise and systems of care. In addition to age, objective measures of patients at higher risk for poor perioperative outcomes already exist. The National Surgical Quality Improvement Program is a risk-adjusted primarily physiologic data set with established definitions and audited validity that is nationally benchmarked.[17,32] The data set could readily be incorporated into national referral guidelines to provide an objective assessment of risk on which to base a decision to refer. An outcomes-driven guideline should lead to overall improvement in quality of care, optimal use of health care resources, and reduction in health care disparity.

There are several intrinsic limitations in our study, which uses administrative data. These include concerns regarding accuracy in case coding of PCs, the retrospective nature, and the lack of risk adjustment. These limitations are potentially balanced by the advantages of interrogating a large random sample of discharge data that has been collected without bias from 1609 unique institutions across the United States.

In conclusion, there is variability in perioperative outcomes across centers in the United States. The establishment of risk- and outcome-based guidelines, rather than volume-based guidelines, will encourage referral patterns with the goal of saving lives, improving quality of care, optimizing health care resource use, supporting communities, and mitigating health care disparity.

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INVITED CRITIQUE

Teh and colleagues' well-written retrospective cohort study used the Nationwide Inpatient Sample to determine perioperative outcomes for major pancreatic resections across surgical centers in the United States. Some 103 222 cases were reviewed during a 16-year period from 1988 to 2003. Using a multivariate model, they determined that age, male sex, medical comorbidity, and hospital volume for each of 3 types of pancreatic resection (pancreatoduodenectomy, distal pancreatectomy, and total pancreatectomy) were independent predictors of operative mortality and postoperative complications. They opine that volume-based referrals undermine local expertise and may leave patients far from supportive social networks. As an alternative, they recommend the establishment of risk-adjusted outcome-based (rather than volume-based) guidelines to improve quality of care, optimize resource utilization, and support local community care delivery.

Teh et al noted that almost 50% of pancreatoduodenectomies performed in the United States were in hospitals with fewer than 6 cases annually. The implications are underscored by the observation that the odds ratio for in-hospital mortality between lowest-volume and highest-volume hospitals was 6.12 for the group aged 55 to 64 years.

There are inherent limitations with the use of administrative databases for outcomes-based research. Of concern is the lack of validation of diagnosis or procedure codes used to identify cases and complications. To this point, I found it surprising that the authors, unlike other investigators,[1] did not find improvement in operative mortality during the 16-year period of study.

The authors are to be commended for a thoughtful approach to outcome-based rather than volume-based guidelines for referral of patients requiring major pancreatic resection. However, implementation will require risk-adjusted patient assessment (eg, the National Surgical Quality Improvement Program) and the development of scorecards for low-volume hospitals that confirm outcomes equal to national benchmarks. This, of course, will take time and resources. In the near-term, regionalization makes sense for uncommon procedures (pancreatectomy) with high risk of operative mortality attributable to low volume.[1] Moreover, current evidence suggests that there is a national failure to operate on early-stage pancreatic cancer.[2] Therefore, candidates for major pancreatic resection are best served by referral to high-volume centers with the resources and expertise to offer operation when indicated and to optimize outcome.

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