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ORIGINAL ARTICLE – HEALTHCARE POLICY AND OUTCOMES

The 90-Day Mortality After Pancreatectomy for Cancer Is Double the 30-Day Mortality: More than 20,000 Resections From the National Cancer Data Base

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ABSTRACT

Background. Operative mortality traditionally has been defined as the rate within 30 days or during the initial hospitalization, and studies that established the volume–outcome relationship for pancreatectomy used similar definitions.

Methods. Pancreatectomies reported to the National Cancer Data Base (NCDB) during 2007–2010 were examined for 30- and 90-day mortality. Unadjusted mortality rates were compared by type of resection, stage, comorbidities, and average annual hospital volume. Hierarchical logistic regression models generated risk-adjusted odds ratios for 30- and 90-day mortality.

Results. After 21,482 pancreatectomies, the unadjusted 30-day mortality rate was 3.7 % (95 % confidence interval [CI] 3.4–3.9 %), which doubled at 90 days to 7.4 % (95 % CI 7.0–7.8). The unadjusted and risk-adjusted mortality rates were higher at 30 days with increasing age, increasing stage, male gender, lower income, low hospital volume, resections other than distal pancreatectomy, Medicare or Medicaid insurance coverage, residence in a Southern census division, history of prior cancer, and multiple comorbidities. The lowest-volume hospitals (<5 per year) performed 19 % of the pancreatectomies, with a risk-adjusted odds ratios for mortality that were 4.2 times higher (95 % CI 3.1–5.8) at 30 days and remained 1.9 times higher (95 % CI 1.5–2.3) at 30–90 days compared with hospitals that had high volumes (≥40 per year).

Conclusion. Mortality rates within 90 days after pancreatic resection are double those at 30 days. The volume–outcome relationship persists in the NCDB. Reporting mortality rates 90 days after pancreatectomy is important. Hospitals should be aware of their annual volume and mortality rates 30 and 90 days after pancreatectomy and should benchmark the use of high-volume hospitals.

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As a group, patients undergoing pancreatectomy at lower-volume hospitals have been repeatedly shown to experience higher perioperative (30-day) and inpatient mortality than patients resected at higher-volume hospitals when examined as a group. This strong inverse relationship between hospital volume and mortality for patients undergoing pancreatectomy has been well established through examination of databases, initially from individual states[1–3] followed by larger and ultimately nationwide studies in the United States and multiple other countries during the past two decades.[4–8]

This study was undertaken to report the National Cancer Data Base (NCDB) outcomes after major pancreatic resection for cancer, and specifically to evaluate the relationship of annual hospital volume (AHV) to mortality at 30, 90, and 30–90 days (conditional 90-day mortality) postoperatively. We hypothesized that conditional 90-day mortality after pancreatectomy would be high, similar to 30-day operative mortality, and that the volume–outcome relationship also would persist.

METHODS

The NCDB, a joint project of the American College of Surgeons' Commission on Cancer (CoC) and the American Cancer Society, includes cancer reports for approximately

70 % of all patients with a new diagnosis of cancer in the United States at approximately 1,500 CoC-accredited facilities, including 74 % of all pancreatic cancers.[9] Using the NCDB, the CoC has the ability to report directly to more than 1,500 cancer programs their individual volume and mortality data and to allow programs to compare their data with all CoC-accredited programs in the United States.

Data for adult patients (age $\geq$18 years) with pancreatic cancer diagnosed between 2007 and 2010 who underwent major pancreatic resection, including pancreaticoduodenectomies as well as total, extended, and distal resections (Facility Oncology Registry Data Standards [FORDS] codes 30–80[10]) were retrieved from the database. Local excisions of tumor (FORDS code 25) were excluded from the study. Surgery dates, last contact dates, and vital status information were used to calculate mortality within 30 and 90 days after the definitive surgery date, as well as mortality 31–90 days after definitive surgery (conditional 90-day mortality).

The hospitals included in the analysis were limited to currently accredited CoC Hospitals that were reporting cases to the CoC throughout the study period (2007–2010). The mean AHV of pancreatectomies was calculated for each eligible hospital for the 4-year period. Hospitals with 40 % or more of cases with missing 30- or 90-day mortality rates were excluded from the study (due to incomplete follow-up data).

Mortality rates were adjusted for demographic and clinical variables in bi- and multivariable analyses. Comorbid conditions available in the NCDB are derived from up to 10 ICD-9-CM codes recorded for each patient and then categorized into 28 Elixhauser comorbidity groups.[11] Studies have shown this method to be a better predictor of outcomes than the Charlson Comorbidity Index.[12,13] Although individual patient income level is not available, the patient zip code of residence is linked to the 2000 U.S. Census Bureau median income for that zip code, which is used in the analysis. Patient residence also is categorized into Census divisions.

Statistical Analyses

Overall 30- and 90-day mortalities by AHV were calculated. Additionally, to allow for the analysis of factors independently associated with mortality after 30 days, conditional 90-day mortality was calculated by excluding deaths occurring within the first 30 days after definitive surgery.

The 30-day and conditional 90-day mortality rates were compared according to AHV, demographics, and clinical characteristics. Statistical significance ($p < 0.05$) and 95 % confidence intervals (95 % CI) were assessed using survey sampling methodology to account for clustering at the hospital level.

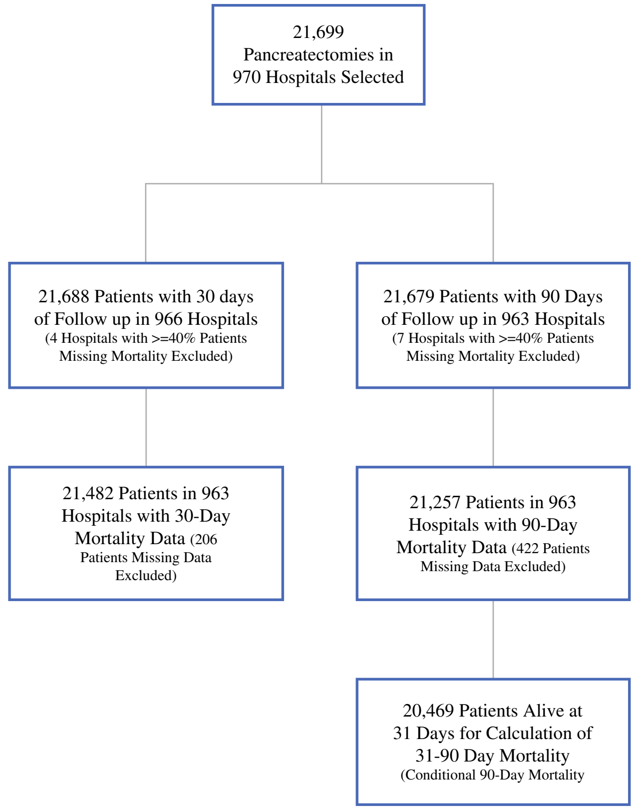

FIG. 1 Cohort selection examining mortality 30 and 90 days after pancreatectomy for cancer from 2007 to 2010 in the NCDB

Multivariate analysis was conducted with a hierarchical regression model fit using the SAS Glimmix procedure (SAS version 9.4, SAS Institute, Cary, NC, USA). All models included random hospital effects to account for clustering of patients in hospitals. Variables in the model included all those significantly associated with either 30-day or conditional 90-day mortality in the bivariate analyses.

RESULTS

A total of 21,699 pancreatectomies for cancer performed at 970 different hospitals were identified in the NCDB data for the 4-year study period. After the exclusion of hospitals missing more than 40 % of 30- or 90-day mortality data, 21,688 patients at 966 hospitals with 30-day mortality data were available, and 21,679 patients in 963 hospitals with 90-day mortality data were available. After the exclusion of another 206 cases (0.9 %) with missing 30-day mortality, 21,482 patients at 966 hospitals with 30-day mortality data were available. A total of 21,257 patients in 963 hospitals with 90-day mortality data were available for analysis. For calculation of mortality occurring between 31 and 90 days, 20,469 patients in 966 hospitals were alive 31 days after surgery (Fig. 1).

TABLE 1 Demographics and clinical percentage distribution of pancreatectomy cases during 2007–2010 ($n = 21,482$)

	Percentage distribution	No. of cases
Age (years)		
18–49	10.2	2,198
50–59	20.1	4,327
60–69	32.2	6,923
70–79	28.3	6,084
≥80	9.1	1,950
Race		
White	84.9	18,247
Black	10.1	2,167
Other	5.0	1,068
Sex[a]		
Male	51.3	11.030
Female	48.6	10,445
Insurance		
Private, self-pay	41.8	11,295
None, Medicaid	5.2	1,448
Medicare	48.9	13,296
Other government, unknown	4.1	879
Median income quintiles[b]		
<$28,000	8.2	1,749
$28–32,000	11.6	2,489
$33–38,000	17.6	3,777
$39–48,000	22.0	4,725
≥$49,000	34.0	7,311
Unknown	6.7	1,431
Census division[c]		
New England	4.1	1,103
Middle Atlantic	17.0	4,598
South Atlantic	21.5	5,883
East North Central	18.4	4,976
East South Central	7.4	2,020
West North Central	7.2	1,924
West South Central	8.9	2,401
Mountain	4.5	1,204
Pacific	10.8	2,906
Out of U.S.	0.3	74
Average AHV of pancreatectomies		
0–4	19.1	4,101
5–9	14.1	3,033
10–19	16.0	3,448
20–29	13.6	2,929
30–39	11.2	2,409
40–49	4.9	1,064
50–59	3.0	641
≥60	18.0	3,857
Surgery type		
Distal	19.2	4,129
Whipple/total/extended	78.9	16,954
Pancreatectomy, type unknown	1.9	399
Stage		
0, 1	20.0	4,298
2	64.3	13,805
3	3.2	689
4	4.8	1,038
Unknown	7.7	1,652
Cancer sequence		
Only or first primary	84.4	18,129
Second or higher primary	15.6	3,353
Neoadjuvant chemotherapy		
No	92.6	19,882
Yes	7.4	1,600
Neoadjuvant radiation		
No	95.9	20,608
Yes	4.1	874

[a] Excluding 7 cases of unknown or other sex

[b] Based on zip code level income from 2000 census

[c] Patient residence. Census region states include the New England (ME, VT, NH, MA, CT, RI), Middle Atlantic (NY, PA, NJ), South Atlantic (WV, MD, DE, DC, VA, NC, SC, GA, FL), East North Central (WI, IL, MI, IN, OH), East South Central (KY, TN, MS, AL), West North Central (ND, SD, NE, KS, MN, IA, MO), West South Central (OK, AR, LA, TX), Mountain (MT, ID, WY, NV, UT, CO, AZ, NM), and Pacific (WA, OR, CA, HI) states

Table 1 presents the distribution of demographic and clinical characteristics. The mean age of the patients was 65 years, with 37 % of the patients 70 years of age or older. About half of patients were male, and most (85 %) were white. Insurance coverage was predominantly Medicare (49 %) or private insurance (42 %). One third of the patients lived in areas with zip codes in the $49,000 or greater median income quintile, and 38 % lived in Middle or South Atlantic census divisions. Approximately 19 % of the pancreatectomies were performed at a facility with an AHV less than 5, and 18 % were performed at a facility with an AHV of 60 or greater.

Less than 20 % of the pancreatectomies were distal resections, with various pancreaticoduodenectomies and extended and total pancreatectomies accounting for 79 %. The remaining 2 % were unspecified pancreatectomies. The diagnosis for 20 % of the patients was stage 1 or noninvasive stage 0 disease, and 64 % had a diagnosis of stage 2 disease. Most patients had no history of cancer (84 %). Only a small percentage of the patients had received neoadjuvant chemotherapy (7 %) or radiation (4 %).

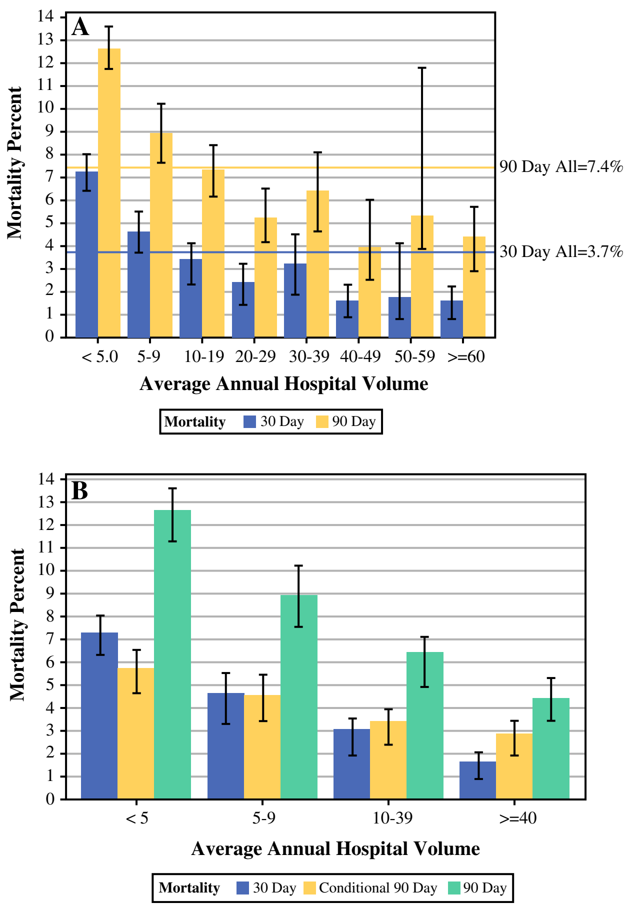

FIG. 2 **a** Unadjusted 30- and 90-day mortality with 95 % confidence intervals during 2007–2010 by average AHV. **b** Unadjusted 30- , 90-day, and conditional 90-day mortality with 95 % confidence intervals during 2007–2010, by average AHV

The unadjusted 30-day mortality rate was 3.7 % (95 % CI 3.4–3.9), based on 788 deaths, whereas the overall 90-day mortality rate was 7.4 % (95 % CI 7.0–7.8), based on 1,574 deaths that occurred during the 90 days after surgery. The conditional 90-day mortality rate was 3.8 % (95 % CI 3.6–4.1), based on 786 additional deaths between 31 and 90 days. Figure 2a displays the overall 30- and 90-day mortality rates by eight AHV groups for 30-day and overall 90-day mortality. The mortality rates were similar for AHVs of 10–39 cases and for an AHV of 40 cases or more, so four AHV groups (0–5, 5–9, 10–39, ≥40 cases) were used in the bi- and multivariate analyses. Figure 2b shows the overall 30- , 90-day, and conditional 90-day mortality rates for these four AHV groups.

Table 2 presents the results for the bivariate analyses of the 30-day and conditional 90-day mortality rates. The 30-day mortality rate was significantly related to AHV, with the lowest-volume hospitals (<5 cases) having an unadjusted mortality rate more than four times that of the highest-volume hospitals (≥40 cases). Specifically, the 30-day mortality rate was 7.2 % (295 of 4,101 patients) at hospitals with an AHV of fewer than 5 cases compared with a 30-day mortality rate of 1.6 % (89 of 5,562 patients) at hospitals performing 40 or more pancreatectomies per year. Other variables significantly associated with 30-day mortality included older age, male sex, Medicare or Medicaid insurance coverage, lower median income, residence in a Southern census division, stage 3 or 4 resections larger than distal pancreatectomy, history of a prior cancer, and nonreception of neoadjuvant radiation.

The variables significantly associated with conditional 90-day mortality were similar to those for 30-day mortality, with the exception of sex, median income, census division, surgery type, radiation, and five Elixhauser conditions. Conditional 90-day mortality also was significantly related to lower AHV, with rates for the lowest-volume hospitals (5.7 %; 95 % CI 5.0–6.5) twice those for the highest-volume hospitals (2.8 %; 95 % CI 2.2–3.4). Other variables with higher mortality rates (similar to those for 30-day mortality) included older age, Medicare coverage, a history of prior cancer, and a higher stage of disease.

The stage 3 patients had the highest 30-day mortality rate of any stage (7.4 %; 95 % CI 5.4–9.40), whereas the stage 4 patients had the highest conditional 90-day mortality rate (10.9 %; 95 % CI 8.8–13.0) by stage. However, the stage 3 and 4 patients accounted respectively for only 3.2 and 4.8 % of all resections.

Table 3 shows the 30- , 90-day, and conditional 90-day mortality by AHV groups, excluding distal pancreatectomy and unknown pancreatectomy to allow examination of the subgroup of pancreaticoduodenectomies, total pancreatectomies, and extended pancreatectomies. Although the overall 30-day mortality is predictably shown to be somewhat higher with distal resections excluded (4.1 %), the relationship to AHV persists.

In the risk-adjusted analysis, the variables found to be significantly associated with 30-day mortality included volume, age, surgery type, neoadjuvant radiation, and nine Elixhauser conditions (Table 4). The AHV remained significant for both 30-day and conditional 90-day mortality, with odds ratios of 4.2 (95 % CI 3.1–5.8) for 30-day mortality and 1.9 (95 % CI 1.5–2.3) for conditional 90-day mortality for the lowest-volume groups (<5 cases) compared with the highest-volume groups (≥40 cases).

The patients 80 years of age or older also had very high odds ratios for both 30-day and conditional 90-day mortality after major pancreatic resection of respectively 4.6 and 7.2 compared with patients younger than 50 years. The significant variables in the 30-day analysis but not in the conditional 90-day analysis included surgery type, neoadjuvant radiation, and five Elixhauser conditions.

TABLE 2 Unadjusted 30- and 90-day pancreatectomy mortality rates by selected demographic, hospital, and clinical characteristics, and by significant comorbid conditions during the 2007–2010 diagnosis years

	30-Day mortality		Conditional 90-day mortality[a]	
	Mortality % (95 % CI)	Deaths/total *n*	Mortality % (95 % CI)	Deaths/total *n*
All cases	3.7 (3.4–3.9)	788/21,482	3.8 (3.6–4.1)	786/20,469
Average annual volume[b,c]				
1–4	7.2 (6.4–8.0)	295/4,101	5.7 (5.0–6.5)	215/3,765
5–9	4.6 (3.8–5.5)	140/3,033	4.5 (3.6–5.4)	128/2,868
10–39	3.0 (2.5–3.5)	264/8,786	3.4 (2.9–3.9)	291/8,455
≥40	1.6 (1.2–2–0)	89/5,562	2.8 (2.2–3.4)	151/5,381
Age (years)[b,c]				
18–49	1.4 (0.9–1.9)	30/2,198	1.2 (0.7–1.6)	25/2,136
50–59	2.3 (1.8–2.8)	99/4,327	2.2 (1.8–2.6)	92/4,188
60–69	3.2 (2.7–3.7)	223/6,923	3.2 (2.7–3.7)	213/6,617
70–79	5.0 (4.3–5.7)	304/6,084	5.6 (4.9–6.3)	323/5,735
≥80	6.8 (5.4–8.1)	132/1,950	7.4 (6.1–8.7)	133/1,793
Sex[b]				
Male	3.9 (3.6–4.3)	433/11,030	3.9 (3.5–4.3)	410/10,499
Female	3.4 (3.1–3.7)	355/10,445	3.8 (3.3–4.2)	376/9,963
Insurance[b,c]				
None/Medicaid	4.2 (3.0–5.4)	47/1,126	3.8 (2.6–5.0)	40/1,060
Private	2.2 (1.9–2.6)	201/8,980	2.5 (2.1–2.9)	215/8,678
Medicare	4.8 (4.2–5.4)	501/10,497	5.1 (4.6–5.6)	503/9,902
Other, unknown	4.4 (2.9–6.0)	39/879	3.4 (1.9–4.8)	28/829
Median Income quintiles[b]				
<$28,000	4.9 (3.9–6.0)	86/1,749	4.6 (3.5–5.6)	75/1,647
$28–32,000	4.7 (3.7–5.7)	117/2,489	4.0 (3.2–4.9)	95/2,350
$33–38,000	3.5 (2.8–4.3)	134/3,777	3.9 (3.2–4.6)	141/3,608
$39–48,000	4.0 (3.4–4.6)	189/4,725	4.1 (3.5–4.7)	184/4,483
≥$49,000	3.0 (2.5–3.5)	220/7,311	3.4 (2.9–3.9)	239/7,018
Unknown	2.9 (1.9–3.9)	42/1,431	3.8 (2.7–4.9)	52/1,363
Census division[b,d]				
New England	2.9 (1.9–4.0)	26/882	2.9 (1.4–4.5)	25/850
Middle Atlantic	3.0 (2.1–3.9)	110/3,638	3.7 (2.9–4.6)	130/3,481
South Atlantic	3.6 (2.7–4.6)	168/4,613	3.7 (3.0–4.5)	164/4,394
East North Central	3.5 (2.9–4.2)	140/3,951	4.1 (3.4–4.9)	157/3,789
East South Central	4.2 (2.7–5.6)	66/1,588	4.8 (3.6–6.0)	72/1,508
West North Central	3.4 (2.0–4.8)	52/1,538	3.4 (2.1–4.7)	50/1,464
West South Central	5.9 (4.5–7.3)	113/1,920	4.3 (3.3–5.3)	77/1,789
Mountain	2.8 (1.7–3.9)	27/965	3.0 (1.9–4.2)	28/928
Pacific	3.7 (2.8–4.6)	85/2,313	3.7 (2.6–4.8)	82/2,207
Stage[b,c]				
0, 1	2.9 (2.3–3.4)	123/4,298	2.2 (1.7–2.7)	90/4,105
2	3.7 (3.2–4.1)	510/13,805	3.8 (3.4–4.2)	501/13,172
3	7.4 (5.4–9.4)	51/689	6.3 (4.3–8.4)	40/630
4	4.8 (3.4–6.2)	50/1,038	10.9 (8.8–13.0)	106/976
Unknown	3.3 (2.3–4.3)	54/1,652	3.1 (2.0–4.2)	1,586
Other primary cancers[b,c]				
Only primary or first of subsequent primaries	3.6 (3.1–4.1)	645/18,129	3.7 (3.3–4.1)	639/17,293
Pancreas 2nd or higher primary (1 or more prior cancers)	4.3 (3.4–5.1)	143/3,353	4.6 (3.8–5.4)	147/3,176

TABLE 2 continued

	30-Day mortality		Conditional 90-day mortality[a]	
	Mortality % (95 % CI)	Deaths/total *n*	Mortality % (95 % CI)	Deaths/total *n*
Surgery type[b]				
Distal	2.1 (1.6–2.6)	87/4,129	3.2 (2.6–3.7)	126/3,999
Whipple/total/extended	4.1 (3.6–4.6)	690/16,954	4.0 (3.6–4.4)	646/16,088
Pancreatectomy, unknown	2.8 (0.9–4.6)	11/399	3.7 (1.4–5.9)	14/382
Neoadjuvant radiation[b]				
Yes	1.3 (0.5–2.0)	11/874	2.6 (1.3–3.8)	22/858
No	3.8 (3.3–4.2)	777/20,608	3.9 (3.5–4.3)	764/19,611
Elixhauser comorbid conditions				
Congestive heart failure[b,c]				
No	3.6 (3.2–4.0)	752/21,016	3.8 (3.4–4.1)	760/20,040
Yes	7.7 (5.2–10.3)	36/466	6.1 (3.6–8.5)	26/429
Cardiac arrythmias[b,c]				
No	3.5 (3.1–3.9)	693/19,734	3.7 (3.4–4.1)	699/18,845
Yes	5.4 (4.2–6.6)	95/1,748	5.4 (4.1–6.6)	87/1,624
Peripheral vascular disorders[b,c]				
No	3.6 (3.2–4.0)	755/20,985	3.8 (3.4–4.1)	758/20,009
Yes	6.6 (4.3–8.9)	33/497	6.1 (3.7–8.4)	28/460
Hypertension[b,c]				
No	4.1 (3.6–4.7)	534/12,980	4.1 (3.7–4.6)	508/12,300
Yes	3.0 (2.5–3.4)	254/8,502	3.4 (3.0–3.8)	278/8,169
Other neurologic disorders[b,c]				
No	3.6 (3.2–4.0)	758/21,202	3.8 (3.4–4.1)	765/20,222
Yes	10.7 (6.7–14.7)	30/280	8.5 (5.0–12.0)	21/247
Chronic pulmonary disease[b]				
No	3.6 (3.2–4.0)	701/19,557	3.8 (3.4–4.2)	707/18,645
Yes	4.5 (3.5–5.5)	87/1,925	4.3 (3.4–5.3)	79/1,824
Diabetes, uncomplicated[b]				
No	3.8 (3.4–4.3)	635/16,258	3.9 (3.5–4.3)	616/15,716
Yes	3.1 (2.5–3.6)	153/4,924	3.6 (3.0–4.1)	170/4,753
Renal failure[b]				
No	3.7 (3.2–4.1)	782/21,421	3.8 (3.5–4.2)	782/20,414
Yes	9.8 (2.1–17.6)	6/61	7.3 (0.2–14.3)	4/55
Liver disease[b]				
No	3.6 (3.2–4.0)	757/21,043	3.8 (3.5–4.2)	771/20,067
Yes	7.1 (4.5–9.6)	31/439	3.7 (1.9–5.5)	15/402
Coagulopathy[b,c]				
No	3.4 (3.0–3.8)	704/20,949	3.7 (3.4–4.1)	748/20,022
Yes	15.8 (12.2–19.4)	84/533	8.5 (5.4–11.6)	38/447
Weight loss[b,c]				
No	3.5 (3.1–3.9)	709/20,182	3.6 (3.2–3.9)	687/19,261
Yes	6.1 (4.6–7.5)	79/1,300	8.2 (6.5–9.9)	99/1,208
Fluid, electrolyte disorders[b,c]				
No	3.2 (2.8–3.6)	594/18,794	3.6 (3.2–3.9)	639/17,995
Yes	7.2 (6.0–8.5)	194/2,688	5.9 (4.8–7.1)	147/2,474
Depression[b]				
No	3.7 (3.3–4.2)	768/20,525	3.9 (3.5–4.2)	757/19,541

TABLE 2 continued

	30-Day mortality		Conditional 90-day mortality[a]	
	Mortality % (95 % CI)	Deaths/total *n*	Mortality % (95 % CI)	Deaths/total *n*
Yes	2.1 (1.2–2.9)	20/957	3.1 (2.0–4.2)	29/928

[a] Conditional 90-day mortality excludes deaths within first 30 days

[b] $p \leq 0.05$, 30-day mortality

[c] $p \leq 0.05$, conditional 90-day mortality

[d] Excludes 74 patients living outside the United States. Census region states include the New England (ME, VT, NH, MA, CT, RI), Middle Atlantic (NY, PA, NJ), South Atlantic (WV, MD, DE, DC, VA, NC, SC, GA, FL), East North Central (WI, IL, MI, IN, OH), East South Central (KY, TN, MS, AL), West North Central (ND, SD, NE, KS, MN, IA, MO), West South Central (OK, AR, LA, TX), Mountain (MT, ID, WY, NV, UT, CO, AZ, NM), and Pacific (WA, OR, CA, HI) states

TABLE 3 Mortality rates (%) by average AHV during 2007–2010, excluding distal pancreatectomies and pancreatectomy type unknown

	30-Day mortality % (95 % CI)	Deaths/total *n*	90-Day mortality % (95 % CI)	Deaths/total *n*	Conditional 90-day mortality (95 % CI)	Deaths/total *n*
Average annual volume[a]						
<5	8.5 (7.4–9.6)	252/2,964	14.2 (12.9–15.5)	418/2,941	6.2 (5.2–7.1)	166/2,689
5–9	5.2 (4.2– 6.2)	125/2,392	9.8 (8.3–11.3)	233/2,371	4.8 (3.8–5.8)	108//2,246
10–39	3.3 (2.7–3.9)	234/7,114	6.7 (5.9–7.5)	476/7,055	3.5 (3.0–4.1)	242/6,821
≥40	1.8 (1.4–2.2)	79/4,484	4.7 (3.8–5.7)	209/4,411	3.0 (2.3–3.7)	130/4,332
Total	4.1 (3.6–4.6)	690/16,954	8.0 (7.3–8.7)	1,336/16,778	4.0 (3.6–4.4)	646/16,088

CI confidence interval

[a] Volume significantly associated with mortality for 30, 90, and conditional 90 day mortality ($p < 0.05$)

DISCUSSION

In addition to confirming the relationship between hospital volumes of major pancreatic resections for cancer and 30-day mortality after pancreatectomy using NCDB data from 2007 to 2010, this study identified a doubling of the 30-day mortality rate by 90 days after surgery. This doubling of the 30-day mortality rate by 90 postsurgical days was seen in all volume groups and not only in low-volume groups, warranting further study to identify the causes of this ongoing and delayed postoperative mortality.

Some of the conditional 90-day mortality seen in the current study likely results from the increased ability to support critically ill patients postoperatively, delaying some postoperative mortality beyond the traditional 30-day period often used to report operative mortality. Even the highest-volume and highest-performing hospitals, as a group, still had an overall 90-day mortality rate of 4.3 %, more than 1 death for every 25 patients resected.

The significantly increased risk of mortality after resection associated with lower AHV was seen in both the unadjusted and risk-adjusted data analyses. The four times higher chance of death within 30 days after a major pancreatic resection, from a rate of 1.6 % at the highest-volume hospitals (≥40 resections per year) to 7.2 % at the hospitals performing fewer than 5 major resections per year (risk-adjusted odds ratio for mortality, 4.2; 95 % CI 3.1–5.8) represents a variation in outcomes as well as an opportunity for improvement in the care of these patients. Hospitals with an AHV of 5–9 per year are shown to have an overall 30-day risk-adjusted mortality rate 2.6 times higher (95 % CI 1.9–3.7) than the highest-volume hospitals (≥40 cases), with an unadjusted 30-day mortality rate of 4.6 % compared with 1.6 %. We also found a smaller, but also statistically significant difference in 90-day conditional mortality based on AHV. In addition to volume, the importance of appropriate patient selection based on other major risk factors for mortality such as age, stage of disease, and comorbidities also must also be emphasized in relation to lower mortality.

In November of 2000, the Leapfrog Group published Patient Safety Standards that recommended evidence-based hospital referral (EBHR) for five high-risk procedures (coronary artery bypass grafting, coronary angioplasty, elective abdominal aortic aneurysm repair, carotid endarteretomy, and esophageal cancer surgery) based primarily on AHV and selected on the basis of

TABLE 4 Adjusted odds ratios (OR) and 95 % confidence intervals (CI) for 30-day and conditional 90-day mortality rates

	30-Day mortality % OR (95 % CI)	Conditional 90-day mortality % OR (95 % CI)
Average annual volume		
≥40	1.0 (reference)	1.0 (reference)
1–4	4.2 (3.1–5.8)	1.9 (1.5–2.3)
5–9	2.6 (1.9–3.7)	1.5 (1.2–2.0)
10–39	1.6 (1.2–2.3)	1.2 (0.9–1.4)
Elixhauser group		
Congestive heart failure[a]	1.5 (1.0–2.1)	1.1 (0.7–1.7)
Cardiac arrhythmias[a]	1.3 (1.0–1.7)	1.2 (1.0–1.5)
Peripheral vascular disorders[a]	1.5 (1.0–2.2)	1.4 (0.9–2.0)
Hypertension	0.6 (0.5–0.7)	0.7 (0.6–0.8)
Other neurologic disorders	2.8 (1.8–4.2)	2.1 (1.3–3.4)
Diabetes, uncomplicated[a]	0.8 (0.6–0.9)	0.9 (0.8–1.1)
Liver disease[a]	2.0 (1.4–3.0)	1.0 (0.6–1.8)
Coagulopathy	3.8 (2.9–4.9)	1.7 (1.2–2.5)
Weight loss[b]	0.9 (0.7–1.2)	1.6 (1.3–2.1)
Fluid and electrolyte disorders	1.6 (1.4–2.0)	1.4 (1.1–1.7)
Age group		
18–49 (reference)	1.0 (reference)	1.0 (reference)
50–59	1.6 (1.0–2.4)	1.9 (1.2–3.0)
60–69	2.3 (1.5–3.4)	3.1 (2.0–4.7)
70–79	3.3 (2.1–5.0)	5.3 (3.4–8.3)
≥80	4.6 (2.9–7.1)	7.2 (4.5–12.0)
Stage		
0, 1	1.0 (reference)	1.0 (reference)
2	1.2 (1.0–1.5)	1.7(1.3–2.1)
3	2.3 (1.6–3.3)	2.9 (2.0–4.3)
4	1.7 (1.2–2.4)	6.0 (4.4–8.0)
Unknown	1.3 (0.9–1.8)	1.6 (1.1–2.3)
Surgery type[a]		
Distal	1.0 (reference)	1.0 (reference)
Whipple/total/extended	2.0 (1.6–2.6)	1.3 (1.0–1.6)
Pancreatectomy, type unknown	1.2 (0.6–2.3)	1.0 (0.6–1.8)
Neoadjuvant radiation[a]		
No	1.0 (reference)	1.0 (reference)
Yes	0.4 (0.2–0.7)	0.8 (0.5–1.2)

Variables significant at $p \leq 0.05$, unless otherwise indicated. Other variables in the 30-day mortality model that are not significant include other cancer primaries, census division, insurance, income, sex, and Elixhauser conditions (pulmonary circulation disorders, chronic pulmonary disease, renal failure, weight loss, and depression)

[a] Nonsignificant 90-day conditional mortality ($p > 0.05$)

[b] Nonsignificant 30-day mortality ($p > 0.05$)

clinical research supporting volume thresholds. They also suggested that risk-adjusted mortality rates, when available, would replace surgical volume.[7] By 2007, volume standards had been set for EBHR for seven high-risk procedures including pancreatectomy (>10 per year), esophagectomy (>13 per year), and bariatric surgery (>99 per year).[8]

Although our methodology and analysis did not allow us to identify an absolute "break point" or optimal minimum AHV, our data suggest "the more the better" and that mortality continues to decline with increasing AHV. However, a threshold of at least 10 major pancreatic resections per year appears to be a reasonable minimum in the absence of accurate outcome data including risk-adjusted mortality.

The overall 30-day mortality rate of 3.7 % in more than 21,000 major pancreatic resections performed at almost 1,000 CoC-accredited hospitals from 2007 to 2010 is significantly lower than reported in earlier studies, indicating that overall mortality has continued to decline after pancreatectomy over time. For example, Kotwall et al.[5], using the National Inpatient Sample, reported an overall mortality rate of 14 % for almost 25,000 patients undergoing pancreatectomy for peri-ampullary cancer from 1988 to 1995. This compares with the overall mortality rate of 4.1 % found in the current study when distal and unknown pancreatectomy were excluded.

The strengths of the current study, which included more than 21,000 patients treated at CoC-approved institutions, were the use of data from the NCDB entered by certified tumor registrars (CTRs) at each institution (not administrative data), the inclusion of only major pancreatic resections, and the very small number of patients with missing mortality data. A weakness of this study was the inability of the NCDB to report completely and accurately on discharge disposition, subsequent readmission dates, and causes of death, making a complete investigation of the causes of ongoing mortality between 30 and 90 days impossible. Other weaknesses included the FORDS manual used by cancer registrars to code the type of pancreatectomy performed, in which the codes for pancreatectomy are vague, overlapping, and ambiguous. Finally, with use of the Elixhauser comorbidity groups taken from ICD-9-CM codes, it is not always clear which ICD-9-CM codes were present at admission and which might have developed after pancreatectomy or as a result of complications, such as coagulopathy. The CoC and others plan to perform a major revision of the FORDS manual to address these latter issues better.

The 90-day mortality rates after major pancreatectomy for cancer are double the 30-day mortality rates. Although all of the causes of this ongoing mortality beyond 30 days after pancreatectomy are not fully known, the reporting of mortality rates 90 days after pancreatectomy is important when hospital mortality rates are examined. The volume–outcome relationship for pancreatectomy at both 30 and 90 days postoperatively is confirmed in the NCDB. Hospitals should be aware of their annual volume and mortality rates 30 and 90 days after pancreatectomies for cancer and should benchmark the use of high-volume hospitals. To aid this process of continuous quality improvement, the CoC currently reports the AHV of major pancreatic resections for cancer (and mortality rates after those resections if more than 10 cases per year are performed) to all CoC-approved programs using NCDB data submitted by the hospitals on an annual basis as part of the Cancer Quality Improvement Program.

DISCLOSURE None.

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