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Authors
Bateni, Sarah B
Olson, Jennifer L
Hoch, Jeffrey S
et al.

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Drivers of Cost for Pancreatic Surgery: It's Not About Hospital Volume

Sarah B. Bateni, MD[1], Jennifer L. Olson, MD[1], Jeffrey S. Hoch, PhD[2], Robert J. Canter, MD[1], and Richard J. Bold, MD[1]

[1]Divison of Surgical Oncology, Suite 3010, Department of Surgery, University of California, Davis Medical Center, Sacramento, CA; [2]Center for Healthcare Policy and Research, University of California, Davis, Sacramento, CA

ABSTRACT

Background. Outcomes for pancreatic resection have been studied extensively due to the high morbidity and mortality rates, with high-volume centers achieving superior outcomes. Ongoing investigations include healthcare costs, given the national focus on reducing expenditures. Therefore, we sought to evaluate the relationships between pancreatic surgery costs with perioperative outcomes and volume status.

Methods. We performed a retrospective analysis of 27,653 patients who underwent elective pancreatic resections from October 2013 to June 2017 using the Vizient database. Costs were calculated from charges using cost–charge ratios and adjusted for geographic variation. Generalized linear modeling adjusting for demographic, clinical, and operation characteristics was performed to assess the relationships between cost and length of stay, complications, in-hospital mortality, readmissions, and hospital volume. High-volume centers were defined as hospitals performing $\geq$ 19 operations annually.

Results. The unadjusted mean cost for pancreatic resection and corresponding hospitalization was \$20,352. There were no differences in mean costs for pancreatectomies performed at high- and low-volume centers [− \$1175, 95% confidence interval (CI) − \$3254 to \$904, $p = 0.27$]. In subgroup analysis comparing adjusted mean costs at high- and low-volume centers, there was no difference among patients without an adverse outcome (− \$99, 95% CI − \$1612 to 1414, $p = 0.90$), one or more adverse outcomes (− \$1586, 95% CI − \$4771 to 1599, $p = 0.33$), or one or more complications (− \$2835, 95% CI − \$7588 to 1919, $p = 0.24$).

Conclusions. While high-volume hospitals have fewer adverse outcomes, there is no relationship between surgical volume and costs, which suggests that, in itself, surgical volume is not an indicator of improved healthcare efficiency reflected by lower costs. Patient referral to high-volume centers may not reduce overall healthcare expenditures for pancreatic operations.

With healthcare costs continually rising in the US, research on this topic has become increasingly important. Surgical expenditures alone are expected to increase by approximately 60% and represent 7% of the US gross domestic product by 2025.[1] Therefore, the primary goal of research related to healthcare costs is to determine modifiable measures that may be employed by hospitals and physicians to reduce costs, while maintaining and/or improving the quality of care provided.[2–4] Pancreatic surgeries are complex operations associated with high morbidity and mortality.[5] Although relatively uncommon procedures, pancreatic resections have been studied extensively in healthcare outcomes research as a model system for informative analysis that may be more broadly generalizable to other surgical procedures.

Hospital volume has consistently been identified as a reliable predictor of perioperative outcomes for pancreatic resections.[5,6] Although definitions have varied, with the

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R. J. Bold, MD
e-mail: rjbold@ucdavis.edu

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threshold for high-volume center designation consisting of performing from 10 to 54 pancreatic resections annually, high-volume centers have consistently demonstrated improved outcomes with respect to hospital length of stay (LOS), morbidity, and perioperative mortality.[6–9] However, the impact of hospital volume on healthcare costs for pancreatic surgery has not been well-established despite evidence suggesting that postoperative complications, increased LOS, and failure to rescue are significant contributors to greater healthcare costs.[10,11] Furthermore, recent evidence suggests that the gap in the rates of both complications and mortality is narrowing, potentially mitigating the impact of perioperative outcomes on costs of high-risk surgical procedures.[12,13] The objective of this study was to expand on previous research and investigate the relationship between the cost of pancreatic surgery with hospital volume and perioperative outcomes, hypothesizing that high-volume centers would be associated with lower costs due to fewer complications and shorter LOS.

METHODS

The research protocol was approved by the University of California, Davis Institutional Review Board. We performed a retrospective analysis of patients with benign and malignant disease who underwent elective pancreatic resections from 1 October 2013 to 30 June 2017 using the Vizient (previously University HealthSystem Consortium) database. The Vizient database consists of hospital- and patient-level administrative data collected from more than 200 medical centers across the US, and has been previously validated as a reliable data source to examine pancreatic surgery outcomes and healthcare costs.[14–16] Patient hospitalizations for partial pancreatic resection were selected from International Classification of Diseases, Ninth and Tenth Revision (ICD-9 and ICD-10), procedure codes (ICD-9: 52.51, 52.52, 52.53, 52.59, 52.7; ICD-10: 0FBG0ZZ, 0FBG3ZZ, 0FBG4ZZ). Total pancreatectomies were not included to improve cohort homogeneity as they represented only 5% of pancreatic operations, with higher complication rates and LOS compared with partial pancreatic resections.[17,18] Patients $\leq$ 18 years of age and non-elective operations were excluded. The final cohort consisted of 27,653 patients treated at 180 hospitals.

Patient demographics, principal diagnosis, medical comorbidities, severity-of-illness scores, and principal payer were abstracted from the Vizient database. Severity-of-illness scores were created by 3 M Health Information Systems based on diagnosis-related groups (DRGs) present on admission, to measure physiologic decompensation or organ system loss of function. The Elixhauser Comorbidity Index (ECI), a validated measure of mortality risk from administrative databases based on 29 diagnoses, was used to assess patient comorbidities.[19–21] High-volume centers were defined as hospitals performing $\geq$ 19 partial pancreatectomies annually. This cut-off was determined based on previous research [22] and sequential regression analyses of this study's cohort finding that $\geq$ 19 pancreatectomies had the optimal fit (R^2) for complications and in-hospital mortality outcomes.

Perioperative complications were identified from ICD-9 and ICD-10 codes for the index hospitalization and included standard complications (i.e. stroke, pulmonary failure, pneumonia, gastrointestinal hemorrhage, surgical site/organ space infections, myocardial infarction, cardiac arrest, pulmonary embolism, deep vein thrombosis, and systemic shock),[23] in addition to clostridium difficile enteritis, delayed gastric emptying, gastro/enterocutaneous fistula, and bile leak. Pancreatic fistula was not included as ICD-9 and ICD-10 lack a specific code for this complication. Prolonged LOS was defined as LOS for the index hospitalization greater than the 75th percentile, i.e. $>$ 10 days;[24] in-hospital mortality was defined as death occurring during the pancreatic resection hospitalization; and failure to rescue was defined as in-hospital death after experiencing one or more postoperative complications.[11]

The primary outcome was total costs of the pancreatic surgery and associated hospitalization. Costs were estimated from the summation of individual itemized charges for the hospitalization in which the pancreatic resection occurred. These charges were multiplied by hospital revenue code-specific cost-to-charge ratios and adjusted or geographic variation with wage indices. Costs were adjusted for inflation to 2016 US dollars.

Statistical Analysis

Patient and operation characteristics were presented as means with standard deviations (SDs), medians with interquartile ranges (IQRs), and frequencies with percentages, as appropriate. Chi square tests and multivariable logistic regression analyses were performed to compare perioperative outcomes for high- and low-volume centers. Generalized linear models were used to analyze costs adjusted for patient covariates with inverse Gaussian distribution and identity or log link, as determined appropriate using the modified Parks and link tests.[25] Separate multivariable models were performed for perioperative outcomes and hospital volume. Multivariable logistic regression models for perioperative outcomes included the following covariates: age, race, sex, severity of illness, ECI, and operation year, type (pancreaticoduodenectomy vs. other partial pancreatectomy), and approach (minimally invasive vs. open). Generalized linear models included these same covariates as well as payer (private insurance, government, or other). Robust standard errors adjusted for clustering of patients at the same hospital was performed. Adjusted mean differences in costs were estimated from the generalized linear model using the predictive margins command (Stata 13; StataCorp LLC, College Station, TX, USA). The Chi square and Kruskal–Wallis tests were used to compare failure-to-rescue rates and LOS by number of complications. All tests were two-sided, and statistical significance was set at $p < 0.05$. Analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC, USA), and Stata 13.

RESULTS

Table 1 describes demographics, clinical characteristics, and perioperative outcomes for patients treated at high- and low-volume centers. Of the 180 hospitals, 98 (54.6%) were high-volume centers and 82 (45.6%) were low-volume centers. Most patients were treated at high-volume centers ($n = 26{,}257$, 95.0%), with only 5.0% ($n = 1396$) of patients treated at low-volume centers. The median annual number of pancreatic resections was 2.5 (IQR 0.5–7.2) at low-volume centers and 58.3 (IQR 34.1–95.5) at high-volume centers. Pancreaticoduodenectomies were more common at high-volume centers (58.8%) than low-volume centers (49.7%, $p < 0.0001$). Minimally invasive surgeries, including laparoscopic and robotic operations, were similar at both high- (14.9%, $n = 3923$) and low-volume centers (16.6%, $n = 232$).

The unadjusted mean cost ± SD for the initial pancreatic resection was \$20,352 ± \$20,301. There were no significant differences in mean costs for pancreatic resection performed at high-volume versus low-volume centers (− \$1175, 95% CI − \$3254 to \$904, $p = 0.27$) [Table 2 and electronic supplementary Table A1]. When analyzing hospital volume as a continuous variable, there continued to be no relationship between hospital volume and costs in univariable ($p = 0.56$) and multivariable models ($p = 0.64$). This absence of relationship between hospital volume and cost is further illustrated in Fig. 1a, which depicts annual hospital volume by mean pancreatic resection costs for each hospital. Furthermore, as shown in Fig. 1b, in subgroup analyses comparing adjusted mean costs at high- and low-volume centers among patients without any adverse outcome (i.e. prolonged LOS, complication, readmission, and in-hospital death), patients with one or more adverse outcomes, and patients with one or more complications, there were no significant differences in mean costs at high- and low-volume centers (mean cost difference − \$99, 95% CI − \$1612 to 1414, $p = 0.90$; − \$1586, 95% CI − \$4771 to 1599, $p = 0.33$; and − \$2835, 95% CI − \$7588 to 1919, $p = 0.24$, respectively).

Adjusted mean differences in pancreatic resection hospitalization costs for perioperative outcomes are presented in Table 2. Prolonged LOS, one or more complications, and in-hospital death were associated with a mean cost increase of \$19,822, \$16,815, and \$41,596, respectively ($p < 0.001$). Patients readmitted within 30 days had a mean cost increase of \$2671 at the initial surgical hospitalization ($p < 0.001$). The number of complications significantly increased pancreatic resection hospitalization costs (Table 3). One complication was associated with a moderate increase in costs (\$7938) compared with no complications ($p < 0.001$); a second complication was associated with a mean cost increase of \$21,351; a third complication was associated with a mean cost increase of \$42,817; a fourth complication was associated with a mean cost increase of \$58,839; and five or more complications were associated with a mean cost increase of \$105,294 (all $p < 0.001$). LOS and rates of failure to rescue increased as the number of complications increased ($p < 0.0001$) (Fig. 2a, b).

To validate the impact of high-volume status, we analyzed these groups based on traditional quality outcomes (Table 1). High-volume centers had lower rates of prolonged LOS, complications, and 30-day readmissions in both unadjusted and multivariable analyses ($p < 0.05$). Although not significant in the univariate analysis ($p = 0.08$), operations performed at high-volume centers were associated with lower odds of in-hospital death compared with those performed at low-volume centers in multivariable analysis ($p = 0.03$).

DISCUSSION

In this study, pancreatic surgery at high-volume centers was not associated with a reduction in healthcare costs. This is surprising as high-volume centers had improved perioperative outcomes, which do significantly impact costs, including decreased rates of complications, prolonged LOS, readmissions, and in-hospital mortality. Such findings raise an important question: how can volume status be associated with improved outcomes (which are associated with a significant reduction in costs), but not be associated with a reduction in overall costs in itself?

A potential explanation for these findings is the small magnitude of the differences in the rates of adverse perioperative outcomes between high- and low-volume centers, and most patients at both high- and low-volume centers do not experience an adverse event, leading to minimal differences in mean costs. We observed an absolute difference

TABLE 1 Patient demographic, clinical, and operation characteristics, and perioperative outcomes at high- and low-volume centers

	High-volume [N = 26,257]	Low-volume [N = 1396]	p value[a]	All patients [N = 27,653]
Age, years [mean (SD)]	62.6 (12.9)	60.9 (13.4)	< 0.0001	62.5 (12.9)
Sex			0.10	
Male	13,203 (50.3)	661 (47.4)		13,864 (50.1)
Race			< 0.0001	
Caucasian	20,862 (79.5)	933 (66.8)		21,795 (78.8)
Black	2546 (9.7)	246 (17.6)		2792 (10.1)
Asian	805 (3.1)	67 (4.8)		872 (3.2)
Other/unknown	2044 (7.8)	150 (10.7)		2194 (7.9)
Diagnosis			< 0.0001	
Malignancy	18,648 (71.0)	913 (65.4)		19,561 (70.7)
Benign tumor	3601 (13.7)	187 (13.4)		3788 (13.7)
Neoplasm of uncertain behavior	718 (2.7)	57 (4.1)		775 (2.8)
Pancreatitis	998 (3.8)	45 (3.2)		1043 (3.8)
Other medical condition	1876 (7.1)	178 (12.8)		2054 (7.4)
Unknown	416 (1.6)	16 (1.2)		432 (1.6)
Severity of illness			< 0.0001	
Minor	13,556 (51.6)	779 (55.8)		14,335 (51.8)
Moderate	10,305 (39.2)	499 (35.7)		10,804 (39.1)
Major	2300 (8.8)	108 (7.7)		2408 (8.7)
Extreme	86 (0.3)	10 (0.7)		96 (0.3)
Elixhauser Comorbidity Index [mean (SD)]	4.3 (8.4)	3.8 (8.3)	0.03	4.2 (8.4)
Operation			< 0.0001	
Pancreaticoduodenectomy	15,453 (58.9)	694 (49.7)		16,147 (58.4)
Partial pancreatectomy	10,804 (41.1)	702 (50.3)		11,506 (41.6)
Minimally invasive resection	3923 (14.9)	232 (16.6)	0.09	4155 (15.0)
Laparoscopic	3003 (11.4)	143 (10.2)		3146 (11.4)
Robotic	920 (3.5)	89 (6.4)		1009 (3.6)
Payer			< 0.0001	
Private insurance	10,910 (41.6)	454 (32.5)		11,364 (41.1)
Government	14,850 (56.6)	867 (62.1)		15,717 (56.8)
Other (e.g. self-pay, charity)	497 (1.9)	75 (5.4)		572 (2.1)
Prolonged length of stay[a]	6384 (24.3)	435 (31.2)	< 0.0001	6819 (24.7)
Adjusted OR (95% CI)[b]	Reference	1.61 (1.42–1.82)	< 0.0001	
Complications[a]	5159 (19.7)	331 (23.7)	0.0002	5490 (19.9)
Adjusted OR (95% CI)[b]	Reference	1.37 (1.20–1.57)	< 0.0001	
Readmissions[a]	4798 (18.3)	296 (21.2)	0.006	5094 (18.4)
Adjusted OR (95% CI)[b]	Reference	1.22 (1.07–1.39)	0.004	
In-hospital mortality[a]	312 (1.2)	24 (1.7)	0.08	336 (1.2)
Adjusted OR (95% CI)[b]	Reference	1.59 (1.03–2.45)	0.03	

Data are expressed as n (%) unless otherwise specified

SD standard deviation, *OR* odds ratio, *CI* confidence interval

[a]Student's t test (continuous) or Chi square test (categorical) analyses unless otherwise stated

[b]Multivariable logistic regression model adjusted for covariates of age, sex, severity of illness, Elixhauser Comorbidity Index, and operation year, type, and approach

in complication and in-hospital mortality rates for high- and low-volume centers of 4.0% and 0.5%, which is markedly smaller than differences noted in earlier research. For example, Birkmeyer and Dimick reported a reduction of in-hospital mortality of 5.3% at high-volume centers (5.0% vs. 10.3% for high- vs. low-volume centers) for

TABLE 2 Adjusted[a] mean differences in healthcare costs for pancreatic resection hospitalizations with adverse perioperative outcomes and volume status

	Mean cost differences	95% CI		*p* value
Complications	$16,815	$15,582	$18,047	< 0.001
Prolonged length of stay	$19,822	$18,557	$21,087	< 0.001
Readmissions	$2671	$2137	$3205	<0.001
In-hospital death	$41,596	$34,484	$48,707	< 0.001
High-volume center	− $1175	− $3254	$904	0.27

CI confidence interval

[a]Adjusted for age; sex; severity of illness; Elixhauser Comorbidity Index; operation year, type, and approach; and payer

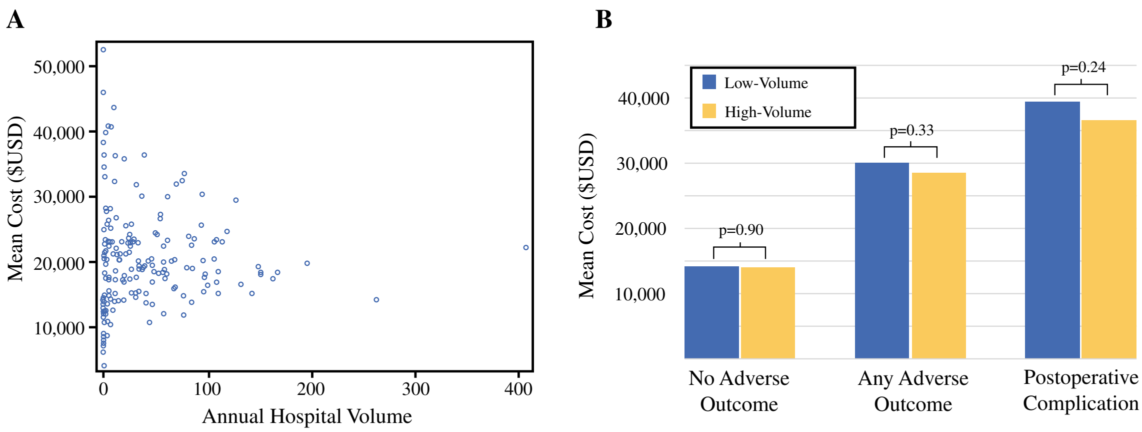

FIG. 1 **a** Scatterplot of the mean cost per hospital by annual pancreatic resection volume. **b** Adjusted mean costs for pancreatic resection hospitalizations at high- and low-volume hospitals among patients who experienced no adverse outcome (i.e. prolonged length of stay, readmission, complication, and in-hospital death), one or more adverse outcomes, and one or more postoperative complications. Costs were adjusted for age; race; sex; severity of illness; Elixhauser Comorbidity Index; operation year, type, and approach; and payer. *USD* US dollars

TABLE 3 Number of complications and adjusted[a] mean difference for pancreatic resection

Number of complications	Mean cost differences	95% CI		*p* value
None (reference)				
1	$7938	$7154	$8721	< 0.001
2	$21,351	$19,072	$23,630	< 0.001
3	$42,817	$38,193	$47,441	< 0.001
4	$58,839	$51,667	$66,011	< 0.001
≥ 5	$105,294	$88,879	$121,909	< 0.001

Hospitalization costs

CI confidence interval

[a]Adjusted for age; race; sex; severity of illness; Elixhauser Comorbidity Index; operation year, type, and approach; and payer

pancreatic resections performed in 2000 using the Nationwide Inpatient Sample (NIS).[26] However, a more recent NIS analysis of pancreatic surgeries showed a trend of improved in-hospital mortality over time, with rates as low as 2.3% in 2011.[13] Additionally, Sutton et al. used the same administrative database—the University HealthSystems Consortium (aka Vizient)—from 2009 to 2011 and observed a higher perioperative mortality rate of 3.5% for pancreatic surgeries performed at low-volume centers, with a mortality rate difference of 2.2% between high- and low-volume centers. With this marked difference, they were able to identify a reduction in costs of approximately $2000 for operations performed at high-volume centers.[27] As we observed a lower rate of in-hospital mortality compared with these earlier cohorts, it is likely that with improved perioperative outcomes at low-volume centers over time,

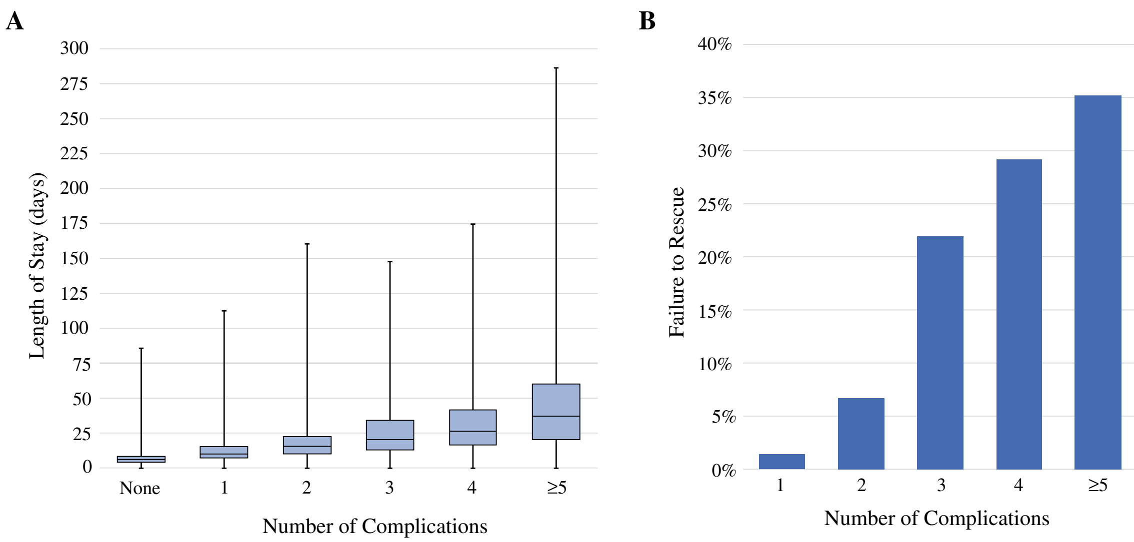

FIG. 2 **a** Length of stay and **b** failure-to-rescue rates by the number of complications among patients who underwent a pancreatic resection. Length of stay and failure-to-rescue rates increased as the number of complications rose (both $p < 0.0001$)

the cost differences have become negligible. This is further supported by a multicenter analysis of Michigan hospitals from 2008 to 2013 by Healy et al., who found similar temporal improvements in complications and 30-day mortality rates after pancreatic resections.[12] Notably, they found that as these outcomes improved, the difference in complication and mortality rates between high- and low-volume centers decreased and, in turn, became non-significant. Therefore, our findings of relatively small, but significant, differences in adverse perioperative outcomes is reflective of this national trend of improved perioperative outcomes, which potentially contributed to the non-significant relationship between surgical volume and costs.

Additionally, the absence of differences in mean costs for patients treated at high- and low-volume centers when stratified by adverse perioperative outcomes suggests that processes of care linked to the management of uncomplicated and complicated pancreatic surgery are similar at high- and low-volume centers. This is likely more pronounced in our study population, which admittedly consists of mostly academic centers, and therefore the processes of care may not be procedure-dependent but based on institutional guidelines, which may be similar among academic centers.

These findings expand on prior research recognizing the significant financial impact of perioperative complications.[11,28–30] Gani et al.[11] also described greater hospitalization costs for pancreatic surgeries with postoperative complications; however, they emphasized the impact of failure to rescue as a major contributor to higher hospitalization costs. Others have argued that failure to rescue, as a quality-of-care metric, is limited as it is a rare event for elective operations, including pancreatic resections, and is influenced by complex factors, including patient preferences.[31,32] The findings from the present study suggest that secondary complications are potentially a more influential and modifiable driver of healthcare costs for pancreatic resections than failure-to-rescue alone. In fact, the greater healthcare costs observed among patients who experience failure to rescue are potentially secondary to the higher costs associated with multiple complications as we found that failure-to-rescue rates were greater among patients who experienced multiple postoperative complications. This is consistent with prior research demonstrating increased risk of failure to rescue among patients with secondary complications.[33] These findings emphasize the need of institutions and providers to focus efforts on reducing the risks of initial and secondary complications to improve patient quality of care and healthcare cost burden.

Additionally, as prolonged LOS was associated with higher healthcare costs for pancreatic surgery patients, LOS is another potential target for cost-reduction efforts. Although complications influence LOS, LOS may also be modified by the implementation of standardized postsurgical management, including enhanced recovery after surgery (ERAS) protocols. In fact, a recent meta-analysis of ERAS programs for pancreaticoduodenectomies demonstrated that implementation of ERAS programs was associated with decreased complications, prolonged LOS, and in-hospital costs.[34]

Although the Vizient database abstracts data from more than 200 hospitals, the majority of hospitals are academic centers, thereby limiting the generalizability of our findings. For example, in addition to temporal improvements in pancreatic surgery outcomes, the inclusion of mostly academic centers in our sample potentially further explains our relatively low mortality and complication rates. Additionally, as we used an administrative dataset, patient, surgeon, and hospital-level details were limited, which hindered our ability to identify pancreatic fistula complications, evaluate the influence of surgeon volume on costs, and to control for detailed hospital-level differences (albeit as most hospitals were academic/teaching centers, these differences were likely negligible). Lastly, although we found that hospital volume status was not associated with differences in pancreatic surgery hospitalization costs, we were not able to determine the specific cause of these findings. This is largely due to the absence of itemized charges available from the Vizient database. Without itemized charges, we were unable to determine the proportion of costs allocated to operative and perioperative care, ancillary staff and services, and laboratory and imaging testing costs at high- and low-volume centers. Future research should further investigate differences in cost allocation at high- and low-volume pancreatic surgery centers to identify additional targets for cost reduction. As surgeon volume and various processes of care (e.g. epidural catheters) have been implicated as potential strategies to reduce costs for pancreatic cancer-related surgery,[35,36] these and other cost-reduction measures require further investigation.

CONCLUSIONS

Although high-volume centers have consistently demonstrated improved perioperative outcomes for pancreatic surgeries, including lower complication and mortality rates, hospital volume was not a significant driver of pancreatic surgery costs. Our findings suggest that coordination of pancreatic surgery in high-volume centers may lead to improved clinical outcomes for a fraction of patients, but is unlikely to broadly reduce healthcare expenditures.

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