Importance of Hospital Volume in the Overall Management of Pancreatic Cancer

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Objective
To determine whether hospital volume is associated with clinical and economic outcomes for patients with pancreatic cancer who underwent pancreatic resection, palliative bypass, or endoscopic or percutaneous stent procedures in Maryland between 1990 and 1995.

Summary Background Data
Previous studies have demonstrated that outcomes for patients undergoing a Whipple procedure improve with higher surgical volume, but only 20% to 35% of patients with pancreatic cancer qualify for curative resection. Most patients undergo palliative procedures instead of a surgical bypass or biliary stent.

Methods
Analysis of hospital discharge data from all nonfederal acute care hospitals in Maryland identified all patients with pancreatic cancer who underwent a pancreatic resection, palliative bypass, or stent procedure between 1990 and 1995. Hospitals (n = 48) were categorized as high-, medium-, and low-volume providers according to their average annual volume of these procedures. Multivariate regression was used to examine the association between hospital volume and in-hospital mortality rate, length of stay, and hospital charges, after adjusting for differences in case mix and surgeon volume.

Results
Increased hospital volume is associated with markedly decreased in-hospital mortality rates and a decreased or similar length of stay for all three types of procedures and with decreased or similar hospital charges for resections and stents. After adjustment for case mix differences, the relative risk (RR) of in-hospital death after pancreatic resection was 19.3 and 8 at the low- and medium-volume hospitals, respectively, versus the high-volume hospital; after bypasses, the RR of death was 2.7 and 1.9, respectively; and after stents, the RR was 4.3 and 4.8, respectively.

Conclusions
Patients with pancreatic cancer who are to be treated with curative or palliative procedures appear to benefit from referral to a high-volume provider.

In the present cost-conscious health care environment, there is considerable interest among health care policy makers and payers concerning the regional referral of patients to hospitals that have special expertise in a given procedure.1,2

One major procedure for which increased volume and experience have been demonstrated to be associated with improved clinical and economic outcomes is pancreatectoduodenectomy—the Whipple procedure.3–6 There is evidence from Maryland, New York, and northern California that short-term outcomes from pancreatectoduodenectomy are significantly better at hospitals where a higher volume of these procedures is performed. On the basis of these studies, some experts have recommended that patients requiring complex procedures such as the Whipple operation be referred to high-volume centers whenever possible.3,4,7

Most studies thus far have focused on evaluating out-
comes for pancreatic resection by either pancreaticoduodenectomy or total pancreatectomy to offer patients the potential for cure. However, resection is possible in only 20% to 35% of patients with pancreatic cancer. Therefore, palliation to relieve symptoms of obstructive jaundice, gastric outlet obstruction, and pain is of primary importance in most patients. Like resection, palliation of pancreatic cancer involves complex surgical and nonsurgical procedures, including biliary bypass, gastrojejunostomy, endoscopic and percutaneous biliary stenting, and chemical splanchicectomy. These procedures may be technically difficult to perform and can be associated with substantial complications, often because of the advanced extent of disease in many patients.

Although significant progress has been made in recent years in the management of pancreatic cancer, less than 20% of all patients diagnosed with the disease survive 1 year, and the overall 5-year survival is less than 5%. Therefore, short-term clinical and economic outcomes are especially important in the setting of a disease such as pancreatic cancer where life expectancy is short. If referral patterns are to be implemented based on outcomes, consideration must be given to the management of the entire spectrum of disease and include evaluation of treatment strategies for both resectable and unresectable tumors. This analysis was performed to determine whether increased hospital volume was associated with a decreased in-hospital mortality rate, a shortened length of stay, and decreased hospital charges for patients undergoing palliative procedures as well as curative surgery for pancreatic cancer.

**METHODS**

**Hospital and Patient Characteristics**

A cross-sectional analysis was performed of hospital discharge data from 48 nonfederal acute care hospitals in Maryland collected by the Maryland Health Services Cost Review Commission (HSCRC). These publicly available data were used to identify all patients with a primary or secondary diagnosis of pancreatic cancer (International Classification of Diseases [ICD-9] diagnosis code 157.x) who underwent a primary procedure that was an attempt at curative resection, a gastrointestinal or biliary–enteric bypass, or endoscopic or percutaneous stent placement between January 1990 and December 1995. For our analyses, three broad procedure categories were created:

- The pancreatic resections group included pancreaticoduodenectomy (ICD-9 code 52.7) and total pancreatectomy (ICD-9 code 52.6).
- The palliative bypasses group included gastrojejunostomy (ICD-9 code 44.39), biliary–enteric bypasses such as cholecysto-, choledocho-, and hepaticojejunostomy (ICD-9 codes 51.31, 51.32, 51.33, 51.36, 51.37, and 51.39), and double bypasses where both gastrojejunostomy and biliary–enteric bypasses were performed together.
- The stents group included common duct exploration for relief of obstruction other than calculus (ICD-9 code 51.42), insertion of choledochohepatic tube for decompression (ICD-9 code 51.43), incision of other bile ducts for relief of obstruction (ICD-9 code 51.49), endoscopic insertion of stent (tube) into bile duct (ICD-9 51.87), and replacement of stent (tube) in biliary or pancreatic duct (ICD-9 97.05). Stent procedures performed on an outpatient basis are not included in the HSCRC database, which captures only procedures performed on patients admitted to the hospital.

The main independent variable in this study, hospital volume, was modeled as a categorical variable. A hospital was included in the analysis if at least one procedure for pancreatic cancer was performed there during the study period. Hospitals were categorized according to their total volume of pancreatic cancer procedures performed in our 6-year study period as follows: a high-volume provider performed 20 or more procedures per year, a medium-volume provider performed 5 to 19 procedures per year, and a low-volume provider performed fewer than 5 procedures per year.

Other independent variables considered in the analysis were patient age, gender, race (white, black, other), urgency of admission (urgent/emergent, elective, other/unknown), and the Dartmouth–Manitoba adaptation of the Charlson comorbidity index. In our analysis, this validated comorbidity score was treated as a continuous variable. Also considered in the models were surgeon volume, measured by the total caseload of pancreatic cancer procedures each surgeon performed during the study period (>50, 5 to 50, <5 total cases), payer status (Medicaid, Medicare, commercial insurance, HMO, other/unknown), place of patient residence (Baltimore inner city, eastern Maryland, central Maryland, southern Maryland, western Maryland, Washington DC suburbs, all other states, foreign countries, and other/unknown), and year of admission (1990 to 1992, 1993 to 1995).

An alternative set of analyses was performed whereby patients who died in the hospital were excluded. We also performed a secondary analysis of how hospital volume was related to outcomes by using an alternative method of categorizing hospital volume in which three high-volume providers accounted for approximately 52% of all pancreatic cancer cases (range 53 to 528 cases during the entire study period), 15 medium-volume providers for 25% of cases (range 15 to 41 cases), and 29 low-volume providers for 23% of cases (range 1 to 14 cases).

**Patient Outcomes**

The outcomes of interest were in-hospital case fatality (referred to as in-hospital mortality rate), mean total hospital length of stay, and mean total hospital charges. Hospital charges were adjusted for inflation based on the appropriate
annual Health Care Financing Administration input price indices, and results are presented in constant 1990 dollars. Because hospital charges are strictly regulated in Maryland, charges serve as a reasonable proxy for actual costs. The average cost-to-charge ratio in Maryland hospitals is about 0.75.\(^{17}\)

**Statistical Analyses**

The distributions of patient characteristics among provider groups were compared using analysis of variance for the continuous variables (age and comorbidity score) and the chi-square statistic for categorical variables. Bivariate analyses were used to determine which variables were associated with outcomes. Based on these analyses, we determined which variables to adjust for in the multivariate regression models.

Multiple linear regression was used to assess how length of stay and charges differed between hospital groups after adjusting for patient age, gender, race, number of comorbidities, and urgency of admission. Separate analyses were performed for each of the three procedure categories. Because mean length of stay and mean total charge data were skewed to the right, a natural log transformation was performed to achieve a more normal distribution. To estimate the adjusted length of stay and average total charges for each group, we transformed the data back to their original scales by exponentiating the values predicted by the models. Poisson regression was used to model the relative risk of in-hospital death between hospital groups, adjusting for case mix. This regression technique often is used when event rates (i.e., mortality) are low.

All statistical inferences pertaining to mean length of stay and hospital charges are based on the log-transformed data. Probability values greater than 0.05 are reported as nonsignificant. All probability values are the results of two-sided tests. Data management and analysis were performed using Paradox 4.5 (Borland International, Scotts Valley, CA) and STATA 5.0 (STATA release 5, College Station, TX), respectively.

**RESULTS**

**Patient Characteristics**

A total of 1236 patients with pancreatic cancer underwent procedures for their disease in Maryland between 1990 and 1995. Of the study population, 449 (36.3%) underwent a Whipple procedure, 47 (3.8%) had a total pancreatectomy, 282 (22.8%) had a double bypass, 260 (21%) had a single bypass, and 198 (16%) had an endoscopic or percutaneous biliary stent placed. Of those who had a single bypass, 133 had a gastrojejunostomy and 127 had a biliary-enteric anastomosis.

There were significant differences in the demographic and clinical characteristics of the patients with pancreatic cancer who underwent procedures at the high-volume provider versus their counterparts at the medium- low-volume providers (Table 1). Patients at the high-volume center were significantly younger, were more likely to be men, were more likely to be white, had fewer comorbid conditions, were more likely to have been referred from out of state, were more likely to have commercial insurance, and were more often admitted on an urgent or emergent basis.

**Hospital Characteristics**

Procedures were performed at 48 of the 52 nonfederal acute care hospitals in the state. The frequency distribution

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**Table 1.** SUMMARY OF PATIENT CHARACTERISTICS BY HOSPITAL VOLUME TIER

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>High Volume(^*) Hospital (n = 528 cases)</th>
<th>Medium Volume(^\dagger) Hospitals (n = 270 cases)</th>
<th>Low Volume(^\ddagger) Hospitals (n = 438 cases)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, years ± SD</td>
<td>64.6 ± 11.2</td>
<td>68.3 ± 12.5</td>
<td>68.6 ± 11.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Range</td>
<td>27–88</td>
<td>23–96</td>
<td>32–94</td>
<td></td>
</tr>
<tr>
<td>Male (%)</td>
<td>55.5</td>
<td>50.4</td>
<td>47.1</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Nonwhite (%)</td>
<td>9.8</td>
<td>26.0</td>
<td>25.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>No major comorbidities (%)</td>
<td>59.3</td>
<td>54.4</td>
<td>48.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Out-of-state residence (%)</td>
<td>46.4</td>
<td>5.2</td>
<td>3.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Insurance (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medicare (%)</td>
<td>51.9</td>
<td>63.0</td>
<td>63.4</td>
<td></td>
</tr>
<tr>
<td>Commercial (%)</td>
<td>42.6</td>
<td>29.3</td>
<td>30.4</td>
<td></td>
</tr>
<tr>
<td>Medicaid (%)</td>
<td>1.5</td>
<td>5.2</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td>HMO/Other (%)</td>
<td>4.0</td>
<td>2.5</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Elective admission (%)</td>
<td>50.4</td>
<td>61.9</td>
<td>65.9</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\(^*\) Performed ≥20 pancreatic cancer procedures per year, 1990–95 (n = 1 hospital).

\(^\dagger\) Performed 5–19 pancreatic cancer procedures per year (n = 7 hospitals).

\(^\ddagger\) Performed <5 pancreatic cancer procedures (n = 40 hospitals).
of procedures performed for pancreatic cancer by hospital was highly skewed (Fig. 1). One institution had 528 cases over the 6-year study period; the next-largest provider had 72 cases. As a result, when hospitals were stratified into our three volume tiers, only one institution met the criteria for a high-volume provider, accounting for 42.7% of the 1236 cases. In contrast, the 40 low-volume providers together accounted for 83% of the hospitals but only 35.4% of all cases. Seven hospitals (14.6%) were medium-volume providers, and they accounted for 21.8% of the pancreatic cancer cases. This pattern was consistent across all three procedures, but it was most pronounced for pancreatic resections. The high-volume center performed 18 times as many resections as the next largest provider (323 vs. 18), and it did greater than three times as many palliative bypasses (144 vs. 39) and stents (57 vs. 17).

Like the frequency distribution of procedures performed for pancreatic cancer by hospital, the distribution by surgeon also was skewed. Of the 1230 cases for whom the surgeon was known, 47.3% had surgery performed by low-volume surgeons, who on average performed fewer than one procedure for pancreatic cancer per year; 92.1% of all surgeons were in this low-volume group (fewer than five total cases). The 27 medium-volume surgeons (5 to 50 total cases) performed 205 procedures, accounting for 7.1% of all surgeons and 16.7% of all cases. Finally, there were four high-volume surgeons (>50 total cases each) who together performed 443 pancreatic cancer procedures, accounting for 36% of all cases. All of these high-volume surgeons were located at the high-volume hospital. More than half of surgeons (56%) performed just one procedure for pancreatic cancer during the study period.

**In-Hospital Mortality Rate**

The unadjusted in-hospital mortality rates were lower at the high-volume provider than at the medium- and low-volume providers across all three procedures (Fig. 2). In-hospital mortality rates for patients undergoing pancreatic resections were 0.9%, 6.9%, and 18.8% at the high-, medium-, and low-volume providers, respectively; for patients undergoing bypasses, they were 4.2%, 10.5%, and 15.3%, respectively; and for patients who received stents, they were 1.6%, 10.9%, and 9.8%, respectively. Differences were statistically significant for pancreatic resections and bypasses. The consistency of the stepwise inverse relation between volume and in-hospital death for resections and bypasses is notable.

Adjustments were made for differences in patient age, gender, race, comorbidity score, and urgency of admission between groups. Patients who underwent a resection had a 19.3 (95% confidence interval [CI] 5.5–68.1) times greater risk of in-hospital death at low-volume providers and an 8 (CI 1.9–34.0) times greater risk of death at medium-volume providers than at the high-volume provider (Table 2). Patients who underwent bypasses had a 2.7 (CI 1.1–6.6) and a 1.9 (CI 0.7–5) times greater risk of death at the low-volume and medium-volume providers, respectively, than at the high-volume provider. Patients who had a stent placed had a 4.3 (CI 0.5–35.3) and 4.8 (CI 0.6–42.3) times greater risk of in-hospital death at low-volume and medium-volume providers, respectively, than at the high-volume provider.

**Length of Stay**

Unadjusted mean length of stay was consistently the lowest at the high-volume provider across procedure categories, and the differences were statistically significant. For pancreatic resections, length of stay at the high-, medium-, and low-volume providers was 18.2, 21.1, and 23.6 days, respectively (p < 0.001); for bypasses, it was 15.1, 17.2, and 19.6 days, respectively (p < 0.001); and for stents, it was 7.6, 8.6, and 11.4 days, respectively (p = 0.04).

The pattern remained after adjusting for differences in patient age, gender, race, comorbidity score, and urgency of admission between groups (Fig. 3). Adjusted mean length of stay was significantly lower for resections at the high-
volume provider versus the medium-volume providers (16.3 vs. 18.8 days, $p = 0.03$) and the low-volume providers (19.4 days, $p = 0.004$), and it was lower than low-volume providers for bypasses (14.3 vs. 16.3 days, $p = 0.02$) and stents (4.6 vs. 6.7 days, $p = 0.02$).

**Hospital Charges**

Differences in mean total hospital charges by hospital volume were less consistent (Fig. 4). Hospital charges for pancreatic resections were lowest at the high-volume provider ($22,379 vs. $26,053 and $33,249 at medium- and low-volume providers, respectively), and these differences were statistically significant ($p < 0.001$). Hospital charges for palliative bypasses were lowest at medium-volume providers ($15,654 vs. $17,377 and $17,483 at the high- and low-volume providers, respectively), but only the difference with low-volume providers was statistically significant ($p = 0.04$). Charges for stents were lowest at high-volume providers ($8373 vs. $9760 and $9564 at the medium- and low-volume providers, respectively), but the differences were not significant. Examination of specific hospital charges (i.e., routine, operating room, supplies, laboratories, radiology, drugs, and therapy) did not identify a consistent source for the differences in charges.

After adjusting for patient age, gender, race, comorbidity score, and urgency of admission, different patterns emerged. Hospital charges for pancreatic resections were significantly lower ($p < 0.001$) at the high-volume provider than at low-volume providers ($20,186 vs. $26,455$); they were also lower than at medium-volume providers ($22,217$), but this difference was not significant. Adjusted hospital charges for palliative bypasses were slightly higher at the high-volume provider than at medium- and low-volume providers ($16,153 vs. $12,761 and $14,463, respectively), but only the difference between the medium-volume providers and the high-volume provider was significant ($p < 0.001$). For stents, adjusted charges at the high-volume provider were slightly less than at the medium- and low-volume providers ($5641 vs. $6828 and $6649, respectively), but the differences were not significant. Adjusted charge estimates are less than the unadjusted charges because the adjustment technique assumes all other covariates in the model are set to the mean of the entire study group, thus limiting the influence of extreme values on the adjusted means.

**Table 2. RELATIVE RISK OF IN-HOSPITAL MORTALITY BY PROCEDURE AND HOSPITAL VOLUME TIER**

<table>
<thead>
<tr>
<th>Procedure</th>
<th>High Volume RR$^\dagger$</th>
<th>Medium Volume RR</th>
<th>p value</th>
<th>Low Volume RR</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resections (n = 496)</td>
<td>1.0</td>
<td>8.0</td>
<td>&lt;0.01</td>
<td>19.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bypasses (n = 542)</td>
<td>1.0</td>
<td>1.9</td>
<td>NS</td>
<td>2.7</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Stents (n = 198)</td>
<td>1.0</td>
<td>4.8</td>
<td>NS</td>
<td>4.3</td>
<td>NS</td>
</tr>
</tbody>
</table>

$^*_{}\text{Hospital volume tiers were defined as: High} = >20 \text{ total cases/year (N} = 1 \text{ hospital); Medium} = 5-19 \text{ cases/year (N} = 7 \text{); and Low} = <5 \text{ cases/year (N} = 40 \text{).}$

$^\dagger_{}\text{Relative risk is 1.0 because the high-volume hospital is the reference group.}$

$^\text{RR} = \text{relative risk; NS} = \text{not significant.}$

**Figure 3.** Adjusted mean length of stay by procedure and hospital volume, 1990 to 1995. Black bars are the high-volume provider, white bars are medium-volume providers, and gray bars are low-volume providers. "p < 0.05, **p < 0.01 vs. the high-volume reference group.

**Figure 4.** Adjusted mean total hospital charges by procedure and hospital volume, 1990 to 1995. Black bars are the high-volume provider, white bars are medium-volume providers, and gray bars are low-volume providers. ***p < 0.001 vs. the high-volume reference group.
Surgeon Volume and Other Possible Confounding Factors

Analyses were performed examining the potential independent effect on outcomes of the volume of pancreatic cancer surgery performed by individual surgeons. Concurrent modeling of both hospital and surgeon volume revealed that the influence on outcomes was exerted mainly by hospital volume. As shown in Table 3, unadjusted in-hospital mortality rates for all pancreatic cancer procedures increased as hospital volume decreased, even when the data were stratified by individual surgeon volume. In contrast, there was no consistent difference in the in-hospital mortality rate related to an individual surgeon’s volume of procedures. These patterns also were seen for length of stay (Table 4). There was no evidence of consistent interaction between surgeon volume and hospital volume.

The findings regarding differences between hospital groups in in-hospital mortality rate, length of stay, and hospital charges were not changed when we included patient insurance status, place of residence, and time period. Removing in-hospital deaths from the analysis of length of stay and total charges had no effect on our conclusions about differences related to hospital volume. In addition, when we used a different categorization of hospital volume in which the three highest-volume hospitals were included in the high-volume group, the models yielded similar results, although the highest-volume hospital’s effects were dampened.

DISCUSSION

Pancreatic cancer is the fifth leading cause of cancer death in the United States, and approximately 28,000 people die of the disease each year.10 Although pancreatic cancer continues to have a poor prognosis, advances in the last decade have led to a better understanding of its molecular genetics and improvements in its management.18 Currently, more patients with pancreatic cancer undergo procedures with curative and palliative intent, magnifying the implications for health care costs and quality of care.

Based on the analysis presented here, it appears that increased hospital volume is associated with a markedly decreased in-hospital mortality rate for both curative surgery and palliative procedures in patients with pancreatic cancer. This finding is more pronounced for pancreatic resections than for palliative procedures. The decreased mortality rate at the high-volume provider is associated with a decreased or similar length of stay than at the medium- and low-volume providers for all procedures, and with decreased or similar hospital charges for resections and stents.

The results of this analysis support earlier studies linking better outcomes with greater volume of cases;7,19–21 this analysis also extends the findings of studies that have shown an association between increased hospital volume and better outcomes for pancreaticoduodenectomy.3–6 It is not just volume of patients per se that is associated with improved performance,16 but volume of similar types of patients—in this case, patients with pancreatic cancer. Some of the previous studies that examined the relation between volume and outcomes from pancreaticoduodenectomy did not take into consideration the diagnosis of pancreatic cancer.3,4,22 Further, the current study includes patients with pancreatic cancer undergoing resection as well as the majority of patients who do not qualify for resection but who benefit from palliative procedures for their advanced disease.

Having more experience with similar types of patients might be associated with improved performance for a number of reasons. High-volume centers may be more likely than low-volume centers to develop a systematic approach and organizational routines for handling such patients by developing critical pathways and involving case managers. This, in turn, may enhance the performance of all partici-

Table 3. IN-HOSPITAL MORTALITY RATES (%) (± SEM) FOR ALL PROCEDURES, BY HOSPITAL AND SURGEON VOLUME TIERS

<table>
<thead>
<tr>
<th>Surgeon Volume†</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>1.8 (0.01)</td>
<td>†</td>
<td>†</td>
<td>1.8 (0.01)</td>
</tr>
<tr>
<td>Medium</td>
<td>4.8 (1.0)</td>
<td>6.9 (0.02)</td>
<td>17.6 (0.05)</td>
<td>10.2 (0.02)</td>
</tr>
<tr>
<td>Low</td>
<td>1.6 (0.02)</td>
<td>11.2 (0.03)</td>
<td>14.2 (0.02)</td>
<td>12.0 (0.01)</td>
</tr>
<tr>
<td>Overall</td>
<td>1.9 (0.01)</td>
<td>9.3 (0.02)</td>
<td>14.7 (0.02)</td>
<td>8.0 (0.01)</td>
</tr>
</tbody>
</table>

* Hospital volume tiers were defined as: High = ≥20 total cases/year (n = 1 hospital); Medium = 5–19 cases/year (n = 7); and Low = <5 cases/year (n = 40).
† Surgeon volume tiers were defined as: High = ≥50 cases/study period (n = 4 surgeons); Medium = 5–50 cases/period (n = 27); and Low = <5 cases/period (n = 342).
‡ No high-volume surgeons in these hospital-volume tiers.

Table 4. MEAN LENGTH OF STAY (DAYS) (±SEM) FOR ALL PROCEDURES, BY HOSPITAL AND SURGEON-VOLUME TIERS

<table>
<thead>
<tr>
<th>Surgeon Volume†</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>16.5 (0.5)</td>
<td>†</td>
<td>†</td>
<td>16.5 (0.5)</td>
</tr>
<tr>
<td>Medium</td>
<td>14.9 (2.4)</td>
<td>16.9 (1.0)</td>
<td>22.7 (2.0)</td>
<td>18.6 (0.9)</td>
</tr>
<tr>
<td>Low</td>
<td>14.0 (1.2)</td>
<td>16.3 (1.0)</td>
<td>18.3 (0.6)</td>
<td>17.3 (0.5)</td>
</tr>
<tr>
<td>Overall</td>
<td>16.1 (0.5)</td>
<td>16.5 (0.7)</td>
<td>19.0 (0.6)</td>
<td>17.2 (0.3)</td>
</tr>
</tbody>
</table>

* Hospital volume tiers were defined as: High = ≥20 total cases/year (n = 1 hospital); Medium = 5–19 cases/year (n = 7); and Low = <5 cases/year (n = 40).
† Surgeon volume tiers were defined as: High = ≥50 cases/study period (n = 4 surgeons); Medium = 5–50 cases/period (n = 27); and Low = <5 cases/period (n = 342).
‡ No high-volume surgeons operated in these hospital volume tiers.
pants in the health care delivery team. Specialized facilities and equipment may be more likely to be on hand to support diagnosis and therapy as the flow of patients becomes larger. The association between increased volume and improved outcomes across all three procedures suggests that there is a significant hospital system effect. By including in our analysis stents (placed percutaneously by invasive radiologists or endoscopically by gastroenterologists), bypasses (performed by general surgeons), and pancreaticoduodenectomies (usually performed by surgeons concentrating in gastrointestinal surgery), we studied health care providers dealing with patients with pancreatic cancer across several specialties.

Our data suggest that the combined "experience effect" of the whole team of pancreatic cancer care providers at a hospital may be more important than the number of operations performed by a particular surgeon. Hospital volume had the strongest and most consistent association with outcomes among the variables included in our data set. It is possible that a large experienced surgical team, specialized nurses, intensivists, anesthesiologists, radiologists, and hospital monitoring procedures are of paramount importance for complex, high-risk procedures performed in patients with a highly morbid disease such as pancreatic cancer. Our findings should be qualified, however, because the distribution of patients by individual surgeon volume was somewhat skewed, with all the high-volume pancreatic surgeons working at the highest-volume hospital. We could not assess the outcomes for high-volume surgeons at medium- and low-volume hospitals, but low-volume surgeons at high-volume hospitals had outcomes similar to those of the high-volume surgeons, whereas low-volume surgeons at low-volume hospitals tended to have the worst outcomes.

An alternative explanation for the association between increased hospital volume and improved outcomes is that low-volume providers treat sicker patients, with a resulting higher mortality rate. Although our data indicate that low-volume providers tend toward having patients with a higher surgical risk (e.g., older with greater comorbidity), the magnitude and statistical significance of the difference in mortality rates between high- and low-volume groups were essentially unchanged by our adjustment for differences in patient case mix. It is possible that adjustment for other potential confounding factors, such as pancreatic cancer staging (which could not be obtained from this hospital discharge data base), could alter the results. However, it seems unlikely that such factors would be responsible for the large differences in mortality rate that we observed, because our adjustment for patient age, sex, comorbidity, urgency of admission, and other factors made little difference in the results.23,24 The percentage of urgent and emergent cases was higher for the high-volume provider than for the medium- and low-volume groups, indicating that severity of illness may actually have been greater at the high-volume hospital.

A third possible explanation for our findings is that practitioners selectively refer patients to hospitals that have better outcomes.25 The independent effect of referral selection on mortality rate was shown in a study of Medicare patients with medical diagnoses treated at the Mayo Clinic and other national referral centers. In that study, patients living outside of Olmstead County, Minnesota, had a 30-day mortality rate that was substantially lower than predicted.26 In our data set, the high-volume center had the largest proportion of out-of-state referrals and a less complex patient case mix. However, adjustment was made for place of residence in our analyses, and this had no significant effect. Therefore, it is unlikely that referral selection bias explains our findings.

This study has several possible limitations. There are undoubtedly some errors in the coding of diagnoses and procedures in the HSCRC data base. However, the coding of major procedures like the ones included in this study tend to be very reliable in this kind of data base; errors usually involve only improper sequencing of codes or failure to code complications,27 which would not affect our results significantly. Many Maryland hospitals also perform internal audits to ensure the accuracy of data they submit to the HSCRC. Because the data base did not have information on cancer staging (e.g., lymph node status, tumor margins, or tumor diameter), we could not adjust for cancer stage in the analysis. However, adjustment for the urgency of admission, which can be viewed as a marker of disease severity, did not change the results.

It would be valuable to report on other outcomes, such as functional status, quality of life, and long-term survival, but these outcomes were not available in the data set. The in-hospital mortality rate for pancreaticoduodenectomies observed in this study was comparable to the 30-day perioperative mortality rate reported at the high-volume hospital.28 Only one patient discharged from the high-volume hospital died at an outside hospital less than 30 days after resection (unpublished data). Thus, the favorable outcomes observed at the high-volume hospital were not the result of patients being prematurely discharged from that hospital. A final limitation relates to generalizability, because there was only one high-volume provider in our main analysis. However, the results were similar when we included three hospitals in the high-volume group.

Overall, these statewide data suggest that patients with pancreatic cancer requiring procedures for their disease may benefit from referral to a high-volume provider, regardless of whether they require curative resection or a palliative bypass or stent. Such referrals might help to decrease the substantial morbidity and mortality rates associated with current patterns of surgical care for patients with pancreatic cancer.

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References


Discussion

Dr. R. SCOTT JONES (Charlottesville, Virginia): Dr. Lilleeoe, congratulations on this very interesting and illuminating study. The review of your material implies that the system is an important part of this. In other words, you looked at surgical volume. But you are looking at your hospital system and saying that that is a big factor here. And if we look at the system, there are multiple components to the system, and you indicated in your analysis that surgeon volume didn’t make any difference.

The question I would like to ask is, in your analysis and your study, do you either have any data or any impressions about the importance of what happens to the patients before they get into your system or into your surgical service? I think this is an important question, because the recognition and the referral of patients with pancreatic cancer is very important. Because many patients have things done to them, some fairly invasive and dangerous things, that may influence their care, particularly if they undergo a resection. And I think that one could infer that in the high volume system that all participants, the surgical and the nonsurgical alike, would be gaining insights into the recognition, the promptness of referral, and the minimizing of unnecessary invasive things. And I wonder if you would tell us whether you think that the high volume hospital had better care and better utilization of resources across the board, surgical and nonsurgical.

Dr. KEITH D. LILLEMOE (Baltimore, Maryland): We do not really have data that we can report that shows how the prereferral management affects our outcome. We certainly do have our biases and are continuously learning how to better manage these patients. In our own hospital over the last 5 to 8 years we have decreased the use of preoperative angiography. Dr. Brennan is now telling us that endoscopic and percutaneous stents are probably harmful and certainly add costs.

We are also totally against preoperative pancreatic biopsies in order to obtain a tissue diagnosis. So certainly if those patients get into our hands in an earlier state, they can get a spiral CT or possibly an MRCP, and probably learn all the data we need to know with one procedure; therefore, avoiding a lot of other costs and potentially morbid procedures.

Dr. JOHN M. HOWARD (Toledo, Ohio): About 30 years ago I presented a paper to this organization which in essence said the