ANNALS OF SURGERY
Vol. 222, No. 5, 638–645

Relation of Perioperative Deaths to Hospital Volume Among Patients Undergoing Pancreatic Resection for Malignancy

Michael D. Lieberman, M.D.,* Harold Kilburn, M.A.,† Michael Lindsey, Ph.D.,† and Murray F. Brennan, M.D.*

From the Department of Surgery, Memorial Sloan-Kettering Cancer Center, New York, New York; and the Department of Health Care Research and Information Services,† Albany, New York*

Objective

The authors examined the effect of hospital and surgeon volume on perioperative mortality rates after pancreatic resection for the treatment of pancreatic cancer.

Methods

Discharge abstracts from 1972 patients who had undergone pancreaticoduodenectomy or total pancreatectomy for malignancy in New York State between 1984 and 1991 were obtained from the Statewide Planning and Research Cooperative System. Logistic regression analysis was used to determine the relationship between hospital and surgeon experience to perioperative outcome.

Results

More than 75% of patients underwent resection at minimal-volume (fewer than 10 cases) or low-volume (10–50 cases) centers (defined as hospitals in which a minimal number of resections were performed in a given year), and these hospitals represented 98% of the institutions treating peripancreatic cancer. The two high-volume hospitals (more than 81 cases) demonstrated a significantly lower perioperative mortality rate (4.0%) compared with the minimal- (21.8%) and low-volume (12.3%) hospitals ($p < 0.001$). The perioperative mortality rate was 15.5% for low-volume (fewer than 9 cases) surgeons (defined as surgeons who had performed a minimal number of resections in any hospital in a given year) ($n = 687$) compared with 4.7% for high-volume (more than 41 cases) pancreatic surgeons ($n = 4$) ($p < 0.001$). Logistic regression analysis demonstrated that perioperative death is significantly ($p < 0.05$) related to hospital volume, but the surgeon's experience is not significantly related to perioperative deaths when hospital volume is controlled.

Conclusions

These data support a defined minimum hospital experience for elective pancreatectomy for malignancy to minimize perioperative deaths.

A therapeutically nihilistic approach to pancreatic cancer was once proposed due to high perioperative mortality and morbidity rates, which may obviate any long-term benefit. During the 1960s and 1970s, pancreatic resection, most commonly a pancreaticoduodenectomy, for carcinoma was associated with a perioperative mortality rate exceeding 20% and a considerably higher morbidity rate.[1-3] More recently, several experienced centers have reported operative mortality rates of less than 5% for pancreaticoduodenectomy or total pancreatectomy performed for cancer.[4-12] These improvements in operative morbidity and mortality rates have also been associated with a modest improvement in long-term outcome for all neoplasms requiring resection of the head of the pancreas.[6-8,10-12] The improved long-term survival, the lack of other suitable treatment modalities, and, especially, the decrease in operative mortality rates support the use of major pancreatic resection for the treatment of peripancreatic malignancies.

Pancreaticoduodenectomy and total pancreatectomy are extensive and uncommon operations, such that any one surgeon or institution will have limited experience. The improved perioperative outcome after pancreatic resection for peripancreatic malignancies reported by experienced centers raises an important question: Can such results in specialized centers be extrapolated to other, less experienced hospitals? Our focus in this study was an examination of the effect of hospital and surgeon volume on perioperative deaths after pancreaticoduodenectomy or total pancreatectomy for the treatment of peripancreatic cancer.

METHODS

We used data from individual patient discharge data abstracts for the years 1984–1991, which we obtained from the Statewide Planning and Research Cooperative System maintained by the New York State Department of Health. This system contains an automated discharge data abstract for each patient discharged from an acute-care facility in New York State. Included in the abstract are the patient's age, sex, race, transfer status (i.e., initial admission or transferred from another hospital), primary payer, admission status (scheduled or unscheduled), medical condition as described by the primary and secondary diagnoses, treatment as described by the primary and secondary procedures (both the diagnostic and procedural codes were derived from the *International Classification of Diseases: Clinical Modification* (9th rev., Medicode, 1994), and disposition.

The Statewide Planning and Research Cooperative System was used to identify all patients with a cancer diagnosis (ICD-9-CM codes 140.0–239.9) who had undergone a total pancreatectomy (ICD-9-CM code 52.6) or a radical pancreaticoduodenectomy (ICD-9-CM 52.7) and discharged in the years 1984–1991. Malignancies included cancer of the pancreas, ampulla, duodenum, distal bile duct, and islet cells.

The volume of operations performed each year was calculated for both hospital and surgeon. Hospital volume was calculated as the number of times a pancreatic resection was performed in the hospital during the year in which the surgery took place. Surgeon volume was defined as the number of times the surgeon performed a pancreatic resection in any hospital for a given year.

Data for each of the 8 years studied were pooled, and logistic regression analyses were performed to determine the extent to which hospital and surgeon volume were significant predictors of death while patient characteristics were controlled. Patient characteristics were treated as covariates and were used to predict death before hospital and surgeon volume were entered into the model. The dependent variable was a binary variable that indicated whether the patient had died in the hospital. Patient characteristics chosen as potential predictors of death were the patient's age, sex, race, admission status (scheduled or unscheduled), and transfer status; number of secondary diagnoses; primary payer; and year in which surgery was performed. Each of these characteristics were also evaluated in a univariate analysis with the chi square test. Significance was ascribed to a p level less than 0.05.

An additional regression analysis, which included only the patient characteristics, was performed to yield a predicted probability of in-hospital death for each patient. This information was used to calculate an indirectly standardized mortality rate for both hospitals and surgeons that would control for differences among patients in severity of illness at admission. Hospitals were then grouped into four volume ranges based on the number of operations performed in each over the 8-year period, and an indirectly standardized rate was calculated for each volume range. Similarly, surgeons were grouped into three volume ranges, and an indirectly standardized rate was computed for each of these volume ranges. Comparisons among the standardized rates for each hospital and surgeon volume group were then made to further assess the relationship between provider volume and patient outcome. The relevance of including a measurement of the severity of illness in the comparison of outcome between hospitals has been reported previously.[13]

Address reprint requests to Murray F. Brennan, M.D., Chairman, Department of Surgery, Memorial Sloan-Kettering Cancer Center, 1275 York Avenue, New York, NY 10021.

Supported by a grant from the Stern Foundation.
Accepted for publication December 19, 1994.

Table 1. MORTALITY AFTER PANCREATIC RESECTION, ACCORDING TO PATIENT, DISEASE, AND ECONOMIC CHARACTERISTICS

Characteristic	No. of Pts	Mortality (%)	p value*
Age (years)			<0.001†
0–50	245	6.1	
51–65	779	10.6	
>65	948	16.6	
Sex			<0.05
Female	952	11.2	
Male	1020	14.5	
Race			<0.001
White	1625	11.8	
Nonwhite	347	18.4	
No. of secondary diagnoses			<0.001‡
0 or 1	179	1.7	
2	201	5.0	
3	265	7.6	
>4	1327	16.7	
Admission status			<0.001
Scheduled	1179	10.4	
Unscheduled	793	16.6	
Transfer to hospital			NS
No	1774	12.8	
Yes	198	13.6	
Payer			<0.001§
Medicare	944	16.8	
Blue Cross	539	8.5	
Other	464	9.9	
Unknown	25	16.0	

NS = not significant.
* Chi square analysis.
† a, b vs. c and a vs. b.
‡ a vs. b, c, d and a, b, c vs. d.
§ a, d vs. b, c.

RESULTS

From 1984 to 1991, 2233 pancreaticoduodenectomies or total pancreatectomies were performed in New York State. Eighty-eight percent of these pancreatic resections were performed for neoplasia. The group of patients (n = 1972) with peripancreatic tumors who underwent pancreatic resection for malignancy are the focus of this analysis.

Demographic and Economic Characteristics

Table 1 shows patient-, disease-, and economically related characteristics with associated perioperative death for patients who had undergone pancreatic resection for cancer. The median age of this group was 64 years, and the female-to-male ratio was 1.1:1. The majority of patients were white (white-to-nonwhite ratio, 4.7:1). Sixty percent of the patients had been scheduled for hospital admission and only 10% had been transferred from another hospital. The hospital bill was paid by Medicare (48%), Blue Cross (27%), another insurer (24%), or unknown (1%).

Primary and Secondary Diagnoses

Most of the pancreatic resections were performed for pancreatic ductal adenocarcinomas (55%) and tumors involving the ampulla of Vater (16%). The remaining major primary diagnoses were distal bile duct adenocarcinoma (8%), duodenal adenocarcinoma (8%), and islet cell tumors (3%).

To control for coexisting and advanced disease, we examined the number of secondary diagnoses. The validity of using this variable in predicting perioperative death has been established previously for coronary artery bypass grafting, abdominal aortic aneurysmectomy, partial gastrectomy, and colectomy.[14] In the current analysis, the variable secondary diagnoses included numerous comorbid (e.g., hypertension, diabetes mellitus, coronary artery disease), tumor-staging (e.g., lymph node positivity, extrapancreatic tumor extension) and postoperative complications (e.g., infection, bleeding). This variable served as an indirect control for severity of illness. The incidence and corresponding perioperative deaths for the number of secondary diagnoses is shown in Table 1. The five most common secondary diagnoses were lymph node positivity (ICD-9 = 1962), secondary malignant neoplasm of other digestive organs (ICD-9 = 1978) (includes pancreatic, bile duct, and ampullary tumor invasion into adjacent organs), postoperative infection (ICD-9 = 9985), cholecystitis (ICD-9 = 5751), and other disorders of the biliary tract (ICD-9 = 5762).

Major postoperative morbidity included in the category of secondary diagnoses that were associated with pancreatectomy were infection and hemorrhage, reported in 12% and 6% of patients, respectively. The corresponding perioperative mortality rate was 19% for infection ($p < 0.05$) and 38% for hemorrhage ($p < 0.05$).

Year of Treatment

Figure 1 illustrates the number of patients who had undergone pancreaticoduodenectomy or total pancreatectomy as well as corresponding mortality rates according to year of treatment. The mean in-hospital mortality rate for the 1972 pancreatic resections performed over this 8-year study was 12.9%. The number of hospitals participating per year ranged from 86 to 108. The number of pancreatic resections performed has tended to increase and the number of perioperative deaths has

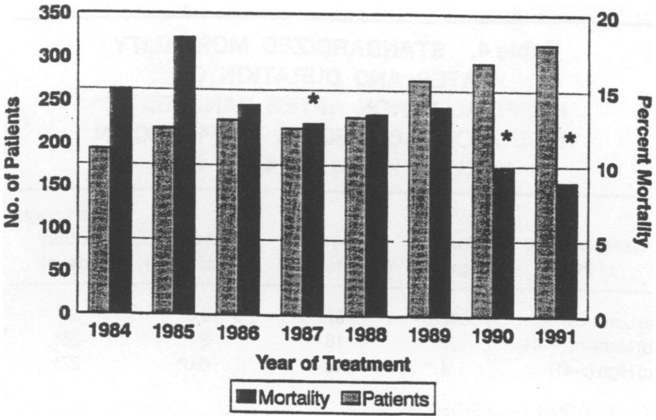

Figure 1. In-hospital crude mortality rates after pancreatic resection according to year of treatment. (*) Chi square ($p < 0.05$) for 1987, 1990, and 1991 *versus* 1984.

Table 3. STANDARDIZED MORTALITY RATES AND DURATION OF HOSPITALIZATION AFTER PANCREATIC RESECTION, ACCORDING TO HOSPITAL VOLUME FROM 1984 TO 1991

Category (No. of Pts.)	No of Hospitals	Percent of Total Patients	Standardized Mortality (%)	Mean Length of Stay (days)
a) Minimal (<10)	124	24	18.9	35
b) Low (10–50)	57	54	11.8	32
c) Medium (51–80)	1	3	12.9	22†
d) High (>81)	2	19	5.5*	27†

* Chi square test $p < 0.001$ for a vs. b, d and a, b vs. d.
† Chi square test $p < 0.05$ for a, b vs. c, d.

decreased for all hospitals in New York State in recent years. Crude mortality rates for pancreatic resection ranged from 18.4% in 1985 to 8.9% in 1991.

Perioperative Deaths

Univariate analysis demonstrated the importance of demographic, economic, disease, and treatment-related characteristics in predicting in-hospital mortality rates after pancreatic resection. Patient characteristics associated with a significantly increased perioperative mortality rate were older age, male sex, nonwhite race, unscheduled admission to the hospital, and Medicare as primary payer (Table 1). Patients with pancreatic, bile duct, or ampullary carcinomas, as compared with duodenal or islet cell tumors, had a significantly increased perioperative mortality rate (Table 2). As the number of secondary diagnoses increased, the perioperative mortality rate also increased significantly (Table 1). Patients who developed postoperative infection or bleeding had a significantly higher in-hospital mortality rate. Finally, pancreatectomies performed in 1987 and in the last 2 years of the study were associated with a significantly decreased perioperative mortality rate.

Hospital and Surgeon Volume

During this 8-year study period, 184 hospitals performed 1972 pancreaticoduodenectomies and total pancreatectomies in the treatment of peripancreatic neoplasms (Table 3). Hospitals were categorized into groups based on the number of patients treated, as follows: minimal-volume (fewer than 10 cases), low-volume (10–50 cases), medium-volume (51–80 cases), and high-volume (more than 81 cases). More than 75% of patients underwent treatment at minimal- or low-volume hospitals, and these hospitals represented 98% of the institutions treating peripancreatic malignancies. The overall crude perioperative mortality rate was 12.9%. Figure 2 demonstrates the inverse relation-

Table 2. MORTALITY AFTER PANCREATIC RESECTION, ACCORDING TO PRIMARY SITE OF TUMOR

Diagnosis	Percent of Patients	Mortality (%)
a) Pancreatic	54.5	14.0
b) Ampulla of Vater	16.2	11.3
c) Bile duct	8.3	15.9
d) Duodenum	7.7	7.3*
e) Islet cell	2.8	0.0*
f) Other	10.5	14.9

* Chi square test, $p < 0.05$ for a, b, c, f vs. d, e.

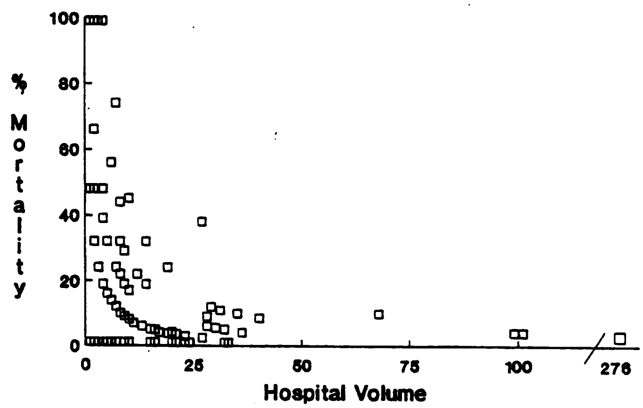

Figure 2. Scattergram of crude in-hospital mortality rates according to hospital volume.

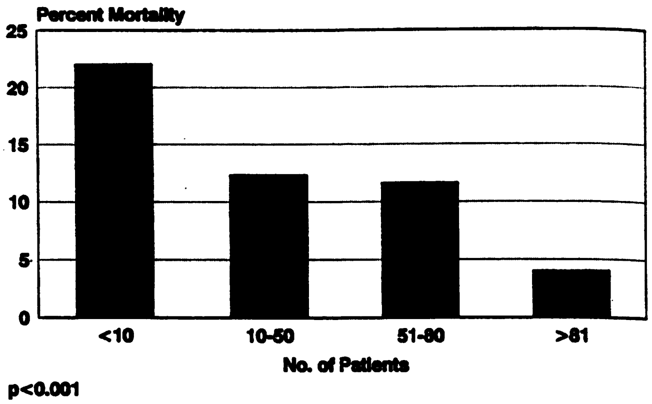

Figure 3. In-hospital crude mortality rates (chi square, $p < 0.001$ for fewer than 10 cases *vs.* 10–50 cases, more than 81 *vs.* fewer than 10, and 10–50 *vs.* more than 81) after pancreatic resection according to hospital volume.

ship between hospital volume and in-hospital deaths. Figure 3 and Table 3 show that both crude and standardized (risk-adjusted) perioperative mortality rates were inversely related to hospital volume ($p < 0.001$). For example, the crude mortality rate for high- compared with minimal-volume hospitals was 4.0% *versus* 21.8%. Similarly, risk-adjusted mortality rate based on the multivariate analysis for high- *versus* minimal-volume hospitals was 5.5% *versus* 18.9% ($p < 0.001$). The influence of hospital volume on duration of survivors' hospitalization is reported in Table 3. High-volume institutions had a mean overall length of stay after pancreatic resection of 27 days, compared with 35 days for minimal-volume hospitals. Patients treated at high- and medium-volume hospitals had a significantly diminished mean length of stay compared with those treated at low- and minimal-volume centers ($p < 0.05$).

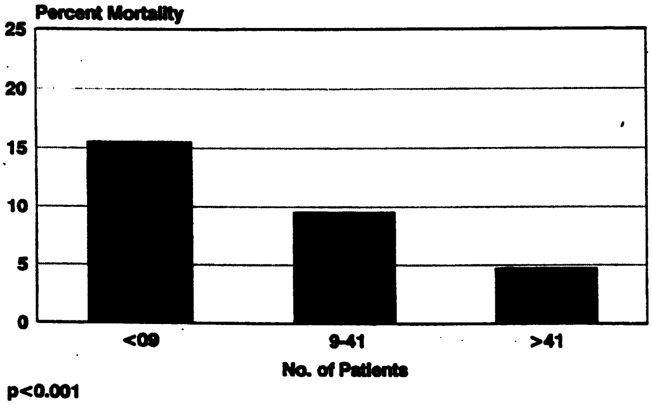

Figure 4. In-hospital crude mortality rates (chi square, $p < 0.001$ for fewer than 9 cases *vs.* 9–41, and fewer than 9 cases *vs.* more than 41) after pancreatic resection according to surgeon volume.

Table 4. STANDARDIZED MORTALITY RATES AND DURATION OF HOSPITALIZATION AFTER PANCREATIC RESECTION, ACCORDING TO PHYSICIAN VOLUME FROM 1984 TO 1991

Category (No. of Pts.)	No. of Surgeons	Percent of Total Patients	Standardized Mortality (%)	Mean Length of Stay (days)
a) Low (<9)	687	67	13.0	34
b) Medium (9–41)	57	18	9.7	26†
c) High (>41)	4	15	6.0*	27†

* Chi square test. $p < 0.001$ for a *vs.* b, c
† Chi square test. $p < 0.05$ for a *vs.* b, c

Figure 4 and Table 4 show comparisons of crude and standardized (risk-adjusted) perioperative mortality rates among surgeon-volume groups for patients treated with pancreatic resection. Surgeons were assigned to the categories of low (fewer than 9 cases), medium (9–41 cases), and high (more than 41 cases) volume based on the number of patients treated during this time period. The overwhelming majority (96%) of surgeons performed less than 9 pancreatectomies over the 8-year period. However, this inexperienced group of general surgeons completed 67% of the pancreatic resections. The perioperative crude mortality rate was 15.5% for low-volume surgeons compared with 4.7% for high-volume pancreatic surgeons. Low-volume surgeons had significantly higher crude ($p < 0.001$) and standardized ($p < 0.001$) perioperative mortality rates and longer mean length of hospital stay (Table 4) ($p < 0.001$).

To control for surgeons who performed pancreatic resection for only a portion of the study period, we performed a separate, extensive analysis. For example, 150 surgeons did not begin operating on the pancreas until 1990. Only eight of these surgeons performed more than two resections in 1990 and 1991 (seven surgeons performed three resections each and one surgeon performed four resections). These 150 surgeons had a crude perioperative mortality rate of 15.0%, which is similar to that for the entire low-volume group (15.5%). Thus, low-volume surgeons had higher perioperative mortality rates after pancreatic resection.

Logistic Regression Analysis

We used a logistic regression analysis to evaluate the influence of hospital and surgeon volume on perioperative mortality rates after pancreatic resection while controlling for other patient- and treatment-related variables. Most importantly, this model demonstrated that

Table 5. LOGISTIC REGRESSION ANALYSIS FOR PANCREATIC RESECTION

Independent Variable	p Value
Hospital volume: decreasing	<0.05
No. of secondary diagnoses: increasing	<0.001
Discharge year 1984–1986, 1988, 1989	<0.05
Age: increasing	<0.05
Male sex	<0.01
Nonwhite race	<0.05
Physician volume	NS
Admission status	
Unscheduled	NS
Transfer	NS
Payer	NS

NS = not significant.
Dependent variable is inhospital mortality.

perioperative death was significantly related to hospital volume when surgeon volume was controlled but that the surgeon's experience was not significantly related to perioperative mortality when the hospital's volume was controlled. (Table 5). This model also demonstrated that older age, male sex, nonwhite race, higher number of secondary diagnoses, and discharge years other than 1987, 1990, and 1991 were predictors of perioperative death.

DISCUSSION

A major goal of this study was to define the relationship of hospital and surgeon experience to number of perioperative deaths after pancreaticoduodenectomy or total pancreatectomy for peripancreatic malignancies. A risk-adjusted perioperative mortality analysis suggested that both hospital and surgeon volume were important determinants of postoperative death. However, the principal finding of the logistic regression analysis was that hospital experience, as opposed to surgeon's experience, was critical in determining perioperative deaths. In fact, for pancreatic resection, there were no threshold hospital volumes beyond which mortality rates plateau. We also observed an inverse relationship between duration of hospitalization and hospital or surgeon volume.

The perioperative mortality rates for high-volume institutions in New York State performing resection of the head of the pancreas are consistent with the recently published perioperative mortality rates of other high-volume institutions.[4–12] For example, Memorial Sloan-Kettering Cancer Center reported a 4.0% operative mortality rate for 372 patients undergoing pancreatic resection from 1983 to 1993 for peripancreatic adenocarcinoma.[12] The operative mortality rate at the Manheim Clinic (Manheim, Germany) was 3.1% for 285 patients who had undergone pancreaticoduodenectomy or total pancreatectomy for neoplasms and chronic pancreatitis between 1972 and 1987, and there were no operative deaths noted in the last 118 pancreaticoduodenectomies.[5,10] Similarly, the Johns Hopkins Hospital reported a 2% operative mortality rate for 47 patients receiving pancreatic resections for malignancy between 1980 and 1986, and more recently, no operative deaths were reported for 145 consecutive patients treated between 1988 and 1991.[4,11] The Mayo Clinic documented a 3.6% operative mortality rate for 279 patients undergoing pancreaticoduodenectomy for benign and malignant disease from 1980 to 1989.[9] In this Mayo series, a univariate analysis identified an increased operative mortality rate with the development of a complication, requirement for early reoperation, and intra-abdominal sepsis. Postoperative mortality rate was not affected by age, sex, operative time, operative blood loss, preoperative weight loss, or preoperative serum bilirubin level. In our analysis of operative mortality in New York State after pancreatic resection, the variables of age, sex, race, and increasing number of secondary diagnoses, a characteristic that indirectly accounts for postoperative morbidity, were all significantly related to early postoperative death. Thus, acceptable perioperative mortality rates for pancreatic resection for peripancreatic malignancies have been achieved in high-volume institutions in New York State as well as in other high-volume centers.

The ability to investigate perioperative morbidity rates, in contrast to mortality rates, in this New York State data base was much more difficult. Inaccurate morbidity rates may be present in the data base because of inadequate medical record documentation, lack of precise definitions for morbid complications in ICD-9 coding, and use of nonmedical personnel in coding for morbidity. Major complications after pancreatic resection are most commonly due to infection from intra-abdominal abscesses, with or without associated pancreatic, biliary, or intestinal fistulas, and hemorrhage. In this analysis, we were able to broadly identify patients with complications secondary to intra-abdominal infection and postoperative intra-abdominal or gastrointestinal hemorrhage. Major infection was found in 12% and hemorrhage in 6% of patients, with associated mortality rates of 19% and 38%, respectively. The Mayo Clinic reported an intra-abdominal abscess rate of 10% and an intra-abdominal bleeding rate of 3% with associated mortality rates of 17% and 38%, respectively.[9] The Manheim Clinic documented bleeding in 6% of their patients but only a 6% mortality rate.[5] Thus, in reviewing the limited morbidity data from the New York State data base and the literature, we could not establish a standard for incidence or death due to a complication.

The central role of hospital experience on outcome after pancreatectomy is probably multifactorial. Pancreatic resection is technically demanding and requires expert surgical and anesthetic care. Furthermore, pancreatic resection, even when performed at high volume institutions, is associated with a greater than 45% morbidity rate.[4-9] The treatment of these complications place extraordinary demands on other medical disciplines, including diagnostic and interventional radiologists, critical care specialists, and infectious disease, nursing, and nutritional support services. The relative contribution of these factors to improved outcome at high-volume centers is unknown.

Other investigators have performed similar volume-outcome analyses for other surgical procedures. Hannan et al. demonstrated that for coronary artery bypass grafting, abdominal aortic aneurysmectomy, partial gastrectomy, and colectomy, surgeon volume was inversely related to perioperative deaths. However, for cholecystectomy, hospital volume was inversely related to perioperative deaths.[14] Interestingly, 11 of 16 procedures did not have volume–outcome relationships. A smaller study did not find a relationship between hospital or surgical volume and perioperative death after coronary artery bypass surgery.[15] Laffel et al. observed an institutional learning curve for cardiac transplantation, but no volume–outcome relationship existed for the experience of the cardiac transplant surgeon.[16] Clearly, outcome from some surgical procedures will be hospital- or surgeon-volume dependent; however, the precise reasons remain obscure.

Over the past decade, the number of patients who have died after undergoing pancreatectomy for the treatment of peripancreatic cancers has declined dramatically. All of the institutions reporting important decreases in operative mortality rates for pancreatic resections would be classified in our scheme as high-volume centers.[4-12] The operative mortality rates are less than 5% and consistent with the mean operative mortality rate of high-volume hospitals in New York State. However, the vast majority of patients with peripancreatic cancers treated by pancreatic resection are being treated at less-experienced institutions by less-experienced surgeons. In New York State between 1984 and 1991, more than 75% of pancreatic resections for peripancreatic cancer were performed at low-volume hospitals, which represent 98% of the institutions performing the procedure. Approximately 67% of pancreatic resections for cancer were performed by low-volume surgeons, who represent 96% of surgeons performing pancreatectomy. In the current study, univariate analysis demonstrated that hospital and surgeon volume was inversely related to in-hospital deaths and duration of hospitalization after pancreatic resection for neoplasms. However, multiple logistic regression analyses indicated that hospital volume was the predominant variable associated with perioperative death. This discrepancy between the univariate and multiple logistic regression analyses is probably related to the observation that many inexperienced surgeons work in low volume hospitals.

These data would appear to support a defined minimum hospital volume for elective cases, which would require some degree of centralization. However, the socioeconomic consequences of such an approach in a large geographic area such as New York State may be unfavorable.

The critical health care issue in this recommendation of centralization is to determine whether transforming low-volume institutions into high-volume institutions will improve outcome. The answer relates to two health care hypotheses: "practice makes perfect," that is, beneficial outcomes are due to greater experience, and "selective referral," that is, high volumes are caused by referral to institutions and surgeons with good outcomes.[17,18] We believe that both hypotheses are valid for pancreatic resection, but detailed analyses are unavailable.

In summary, we established with this analysis that the experience of an institution is associated with perioperative death and duration of hospitalization when controlling for patient characteristics and comorbidities. Considering the economic and social turmoil in today's health care industry, such data are a beginning in the quest to include outcome information in a cost-effective analysis.

References

1. Whipple AO, Parsons WB, Mullins CR. Treatment of carcinoma of the ampulla of Vater. Ann Surg 1935; 102:763–779.
2. Gilsdorf RB, Spanos P. Factors influencing morbidity and mortality in pancreaticoduodenectomy. Ann Surg 1973; 177:332–337.
3. Lansing PB, Blalock JB, Oschner JL. Pancreaticoduodenectomy: a retrospective review, 1949–1969. Am Surg 1972; 38:79–86.
4. Crist DW, Sitzmann JV, Cameron JL. Improved hospital morbidity, mortality, and survival after the Whipple procedure. Ann Surg 1987; 206:358–365.
5. Trede M, Schwall G. The complications of pancreatectomy. Ann Surg 1988; 207:39–47.
6. Geer RJ, Brennan MF. Prognostic indicators for survival after resection of pancreatic adenocarcinoma. Am J Surg 1993; 165:68–72.
7. Pellegrini CA, Heck CF, Raper S, Way LW. An analysis of the reduced morbidity and mortality rates after pancreaticoduodenectomy. Arch Surg 1989; 124:778–781.
8. Grace PA, Pitt HA, Tompkins RK, et al. Decreased morbidity and mortality after pancreaticoduodenectomy. Am J Surg 1986; 151: 141–149.
9. Miedema BW, Sarr MG, vanHeerden JA, et al. Complications following pancreaticoduodenectomy: current management. Arch Surg 1992; 127:945–949.
10. Trede M, Schwall G, Saeger HD. Survival after pancreaticoduode-

nectomy: 118 consecutive resections without an operative mortality. Ann Surg 1990;211:447–458.

11. Cameron JL, Crist DW, Pitt HA, et al. One hundred and forty-five pancreaticoduodenectomies without mortality. Ann Surg 1993; 217:430–438.
12. Brennan MF, Kinsella TJ, Casper ES. Cancer of the pancreas. In: DeVita VT, Hellman S, Rosenberg SA, eds. *Principles and Practice of Oncology.* 4th ed. Philadelphia, Pa: J.B. Lippincott; 1993:849–882.
13. Green J, Winfeld N, Sharkey P, Passman LJ. The importance of severity of illness in assessing hospital mortality. JAMA 1990;263: 241–246.
14. Hannan EL, O'Donnell JF, Kilburn H, et al. Investigation of the relationship between volume and mortality for surgical procedures performed in New York State hospitals. JAMA 1989;262:503–510.
15. Zelen J, Bilfinger TV, Constantine AE. Coronary artery bypass grafting: The relationship of surgical volume, hospital location and outcome. NY State J Med 1991;91:290–292.
16. Laffel GL, Barnett AI, Finkelstein S, Kaye MP. The relation between experience and outcome in heart transplantation. N Engl J Med 1992;327:1220–1225.
17. Luft HS, Hunt SS, Maerki SC. The volume-outcome relationship: practice makes perfect or selective referral patterns? Health Serv Res 1987;22:157–182.
18. Luft HS. The relations between surgical volume and mortality: an exploration of casual factors and alternative models. Med Care 1980;18:940–959.