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Outcomes of pancreatic debridement in acute pancreatitis: analysis of the nationwide inpatient sample from 1998 to 2010

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Abstract

BACKGROUND: The objective of this study was to perform a national review of patients with acute pancreatitis (AP) who undergo pancreatic debridement (PD) to evaluate for risk factors of in-hospital mortality.

METHODS: The Nationwide Inpatient Sample was used to identify patients with AP who underwent PD between 1998 and 2010. Risk factors for in-hospital mortality were assessed with multivariate logistic regression.

RESULTS: From 1998 to 2010, there were 585,978 nonelective admissions with AP, of which 1,783 (.3%) underwent PD. From 1998 to 2010, the incidence of PD decreased from .44% to .25% ($P < .01$) and PD in-hospital mortality decreased from 29.0% to 15% ($P < .05$). Of patients undergoing PD, independent factors associated with increased odds of mortality were increased age (odds ratio [OR] 1.04, confidence interval [CI] 1.03 to 1.05; $P < .01$), sepsis with organ failure (OR 1.76, CI 1.24 to 2.51; $P < .01$), peptic ulcer disease (OR 1.83, CI 1.02 to 3.30; $P < .05$), liver disease (OR 2.27, CI 1.36 to 3.78; $P < .01$), and renal insufficiency (OR 1.78, CI 1.14 to 2.78; $P < .05$).

CONCLUSIONS: The incidence and operative mortality of PD have decreased significantly over the last decade in the United States with higher odds of dying in patients who are older, with chronic liver, renal, or ulcer disease, and higher rates of sepsis with organ failure.

Surgical treatment of acute pancreatitis (AP) has been a topic of controversy because it was first proposed in 1886 by Nicholas Senn,[1] when he stated that "…the timely removal of the necrosed organ by surgical interference would add to the chances of recovery." Thus began the consideration of operative management for AP and subsequently, surgeons have continuously pursued the optimal operative approach for this difficult disease.[2] With the discovery of a relationship between serum amylase and AP, nonoperative management of mild AP became the mainstay. Over the last century, however, surgeons have continued to struggle with the more severe form of the disease associated with pancreatic necrosis, sepsis, and organ failure, in hopes to determine which patients may benefit from surgical intervention and at what point in the disease process.[3]

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Evaluation of surgical outcomes in AP has largely been limited to retrospective series, the largest of which are a 16-year experience with 250 patients and a 19-year experience with 285 patients undergoing pancreatic debridement (PD) with a postoperative mortality ranging from 25% to 39%.[4,5] Advances in imaging and critical care, a revolution in percutaneous, endoscopic, and minimally invasive surgical techniques, and an international consensus on how to define the varying stages and severity of AP have resulted in improved outcomes for patients with AP.[6–8] During the past decade, the surgical management of AP has evolved to incorporate these less invasive interventions in contrast to the conventional, open PD performed via a laparotomy. For instance, a recent, multicenter trial from 21 Dutch hospitals inclusive of all patient admissions with pancreatic necrosis revealed that a conservative, nonoperative or minimally invasive management approach was successful for the majority of patients with low in-hospital mortality.[9] Similarly, a recent prospective randomized trial of 88 patients showed less morbidity with equivalent in-hospital mortality with a “step-up” approach to PD utilizing percutaneous and minimally invasive surgical drainage as compared with conventional open PD.[10] Presently, severe AP with necrosis still has a mortality of 7% to 19%[7,8,10] and the overall mortality in those undergoing operative treatment for both sterile and infected necrosis remains substantial despite significant advances. Large population-based administrative databases, such as the Nationwide Inpatient Sample (NIS), have been successfully utilized to evaluate surgical outcomes of commonly performed pancreatic operations.[11–13] However, national evaluation of surgical outcomes in AP has been limited.[7,14] The aim of this study was to utilize a large national database to evaluate outcomes of patients admitted with AP who undergo PD. The proposed hypothesis was that a large sample of patients undergoing operative intervention for AP over more than a decade would provide insight into trends in the utilization of PD, the in-hospital mortality following PD, and factors associated with mortality after PD.

Methods

Data source

The data utilized for this study were extracted from the NIS, which is the largest publicly available all-payer inpatient care database in the United States and contains data from approximately 8 million hospital stays each year.[15] The database is maintained by the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality. The NIS contains a 20% stratified sample of nonfederal hospitals within the United States, including academic, specialty, community, and general hospitals but excludes long-term facilities. In 2010, it included 1,051 hospitals from 45 states and contained all patients discharged from the selected hospitals for a given year.[15] In this study, the NIS-implemented weighting strategy[15] was not used and only actual patient data contained in the database were used for analysis. Each inpatient record in the NIS represents a single-hospital discharge and includes demographic data, admission type, transfer status, up to 15 individual primary and secondary diagnoses and procedures for the hospitalization (based on International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] and Procedure Related [ICD-9-PR] coding), payer status, total hospital charges, length of stay (LOS), and hospital characteristics (urban vs rural, region, teaching status, and bed size). Additional comorbidities identified and compared are based on the NIS *Disease Severity Measures file*, which is coded individually for each inpatient stay record.

The NIS does not contain any patient identifiers and therefore does not require institutional review board approval before use; however, it requires all users to complete the Healthcare Cost and Utilization Project data use agreement training before performing any scientific analysis. When the number of patients reported in a category is less than 10, the exact proportion is not reportable to maintain patient confidentiality; however, the reported *P* value is calculated with the exact number of observations in the analysis.

Inclusion and exclusion criteria

The NIS was sampled for all years between 1998 and 2010. All patients aged 18 years and older with a nonelective admission and ICD-9-CM diagnosis code of AP (577.0) were initially queried. ICD-9-CM code 577.0 for AP does not include subcoding and is all-inclusive for “abscess of pancreas,” “necrosis of pancreas: acute and infective,” and “pancreatitis: not otherwise specified, acute (recurrent), apoplectic, hemorrhagic, subacute, and suppurative.” Additionally, a diagnosis code for “necrotizing pancreatitis” does not exist in the ICD-9-CM. Any patient with a diagnosis code of chronic pancreatitis (577.1), benign neoplasm of the pancreas (211.6, 211.7), or malignant neoplasm of the pancreas (157 x, where $x = 0$, 1, 2, 3, 4, 8, or 9) were excluded from analysis to limit miscoding of patients undergoing pancreatic resections for other types of pancreatic pathology.

Pancreatic debridement

Patients who met inclusion criteria were stratified as undergoing PD based on the presence of ICD-9-PR code 52.22 (other excision or destruction of lesion or tissue of the pancreas or pancreatic duct) or 52.59 (other partial pancreatectomy), the 2 nonendoscopic procedure codes for debridement of pancreatic tissue. Any patient with an ICD-9-PR code of 52.51 (proximal pancreatectomy), 52.52 (distal pancreatectomy), 52.53 (radical subtotal pancreatectomy), 52.6 (total pancreatectomy), and 52.7 (radical pancreaticoduodenectomy) were excluded from analysis to limit miscoding of patients undergoing formal pancreatic resections for other pancreatic pathology. Procedural code for "necrosectomy" does not exist in the ICD-9-PR.

Acute pancreatitis etiology, complications, and comorbidity weighting

All patients who met inclusion were further stratified into 4 mutually exclusive etiologies of AP (biliary, alcohol, other, and idiopathic) based on ICD-9-CM and ICD-9-PR coding as previously described by Chen et al[16] (Appendix A). Postoperative in-hospital complications were evaluated for all patients undergoing PD based on ICD-9-CM codes and were grouped into 8 categories (mechanical wound complications, infections, urinary complications, pulmonary complications, gastrointestinal complications, cardiovascular complications, systemic complications, complications during the procedure), as described by Guller et al[17] and are listed in Appendix B. The NIS only contains in-hospital complications and all patient complications after discharge are not available for evaluation. Additional diagnosis and procedure codes used for extrapolation of outcomes in this study sample are listed in Appendix C.

To measure the extent of comorbid disease between groups, the Charlson comorbidity index (CCI) was calculated based on ICD-9-CM coding. The CCI is used to calculate mortality risk based on 19 weighted comorbidities[18] and 3 of the cancer-related comorbidities have since been combined for a total of 17 comorbidities. Despite some underreporting in administrative data, the NIS has been shown to accurately report comorbidity presence and the CCI has been shown to better predict mortality than many individual comorbidities.[19] The algorithm developed by Quan et al[20] was utilized to determine the CCI from ICD-9-CM coding available in the NIS data for our analysis of PD in AP. The use of CCI, as described above, has been applied to surgical outcomes in studies utilizing the NIS to examine the burden of comorbid disease with success.[21] Additionally, sepsis with organ failure (ICD-9-CM 995.92) was evaluated for all AP patients and those undergoing PD from 2002 (the inception of the coding) to 2010.

Statistical analysis

Analysis of data was performed utilizing SAS version 9.3 (SAS Institute, Inc, Cary, NC). Pearson's chi-square and Fisher's exact tests were used for categorical variables and the frequencies of variables expressed were as a percentage of the group of origin. Wilcoxon–Mann–Whitney test was utilized for continuous and ordinal variables and frequencies of continuous variables were reported as means ± standard deviation. All group comparisons were unpaired. Statistical significance was set at $P < .05$ and all reported P values are 2-tailed. Multivariate logistic regression utilizing the forward stepwise selection method was performed to evaluate risk factors for increased odds of mortality in patients undergoing PD.

Results

From 1998 to 2010, the NIS contained 585,978 nonelective admissions with AP;584,195 were treated without PD (non-PD) and 1,783 (.3%) underwent PD. Over the 13 years of our study, the incidence of PD trended from .44% to .25% ($P < .0001$) (Fig. 1). Of the patients undergoing PD, 1,387 (78%) survived to discharge with 391 (22%) dying

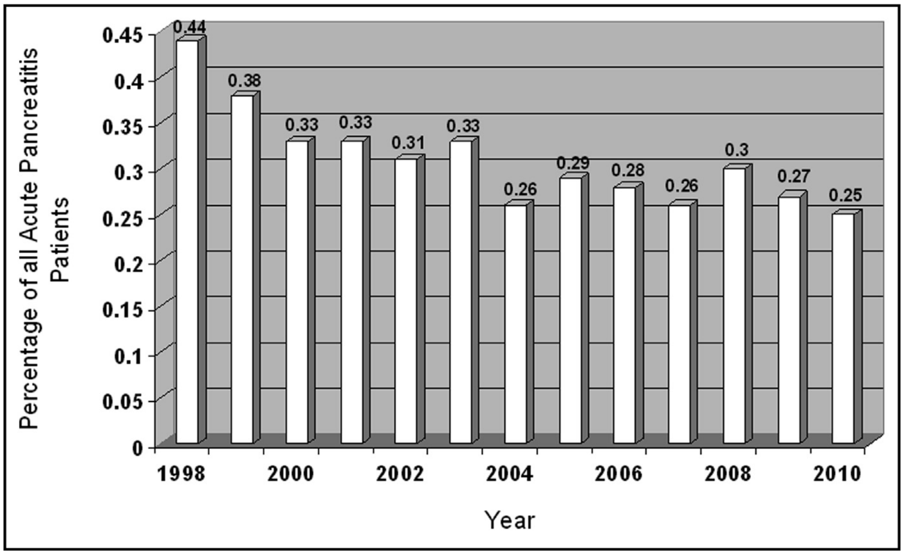

Figure 1 Incidence of pancreatic debridement in patients with acute pancreatitis by year. * $P < .05$, significant difference between 1998 and 2010.

during their hospitalization. Five patients did not have mortality data entered and were excluded for analysis of factors associated with mortality.

From 1998 to 2010, in-hospital mortality in non-PD patients decreased from 3.9% to 2.7 % ($P < .05$) and it decreased from 29% to 15% in those undergoing PD ($P < .05$) (Fig. 2). When stratified into 3 distinct time periods (ie, 1998 to 2001, 2002 to 2005, 2006 to 2010), there was a significant downward trend in mortality in PD patients throughout the last decade ($P < .05$) (Fig. 3).

Analysis of demographics, comorbidities, and AP etiology subtype for PD versus non-PD patients and those undergoing PD survival versus mortality can be found in Table 1. Patients undergoing PD compared with non-PD were older and more often Caucasian men, with lower CCI, and of biliary and idiopathic AP subtype. In patients undergoing PD who survived compared with those who died, patients suffering in-hospital mortality were older, less often Caucasian, with significantly more individual comorbidities and higher CCI. Interestingly, AP etiology was not significantly associated with mortality.

Patients undergoing PD also had significantly more additional procedures performed than non-PD patients, including higher rates of percutaneous drainage procedures, endoscopic retrograde cholangiopancreatography, and pancreatic aspiration; however, additional procedures had little association with mortality (Table 2). When stratified into 3 distinct time periods (ie, 1998 to 2001, 2002 to 2005, 2006 to 2010), the rate of percutaneous abdominal drainage in PD patients increased significantly from 12.1% to 14.3% to 20.3%, respectively ($P < .01$).

As would be expected, patients undergoing PD had a significantly higher rate of sepsis with organ failure (24.8% vs 1.8%; $P < .05$) compared with non-PD patients. In those undergoing PD, sepsis with organ failure was more often present in those who died than those who survived to discharge (43.7% vs 20.0%; $P < .05$).

When comparing postoperative complications, PD patients who died had significantly higher rates of postoperative pulmonary (23.0% vs 18%), cardiac (6.1% vs 2.6%), and procedural complications (10.2% vs 6.3%), but lower rates of postoperative infection (6.4% vs 9.7%) and gastrointestinal complications (2.8% vs 7.1%) than PD patients who survived. There was no difference in postoperative wound or urinary complications between PD patients who died and those who survived to discharge ($P > .05$).

When evaluating the hospitalizations of patients with AP undergoing PD compared with non-PD (Table 3), those undergoing PD were more likely to be transfers (3.4% vs 25.7%, $P < .05$). Of patients who underwent PD, those who suffered in-patient mortality were more likely to have been transferred (24.3% vs 30.1%, $P < .05$). Disposition in PD patients was routine in less than a quarter of the patients, with many patients being discharged to short-term hospitals (3.4%), another facility (29.2%), or home with home health care (23.1%). As would be expected, total hospital charges for patients undergoing PD were nearly 10 times that of patients not undergoing PD. Debridement was more often performed at large, urban, teaching hospitals and in areas of higher median household income by zip code (Table 4). By region of the country, a higher proportion of patients in the Northeast underwent PD. However, hospital size, teaching status, urban or rural location, and geographic region were not significantly associated with mortality in patients who underwent PD. As would be expected, there was a higher mortality in Medicare patients, presumably associated with older age.

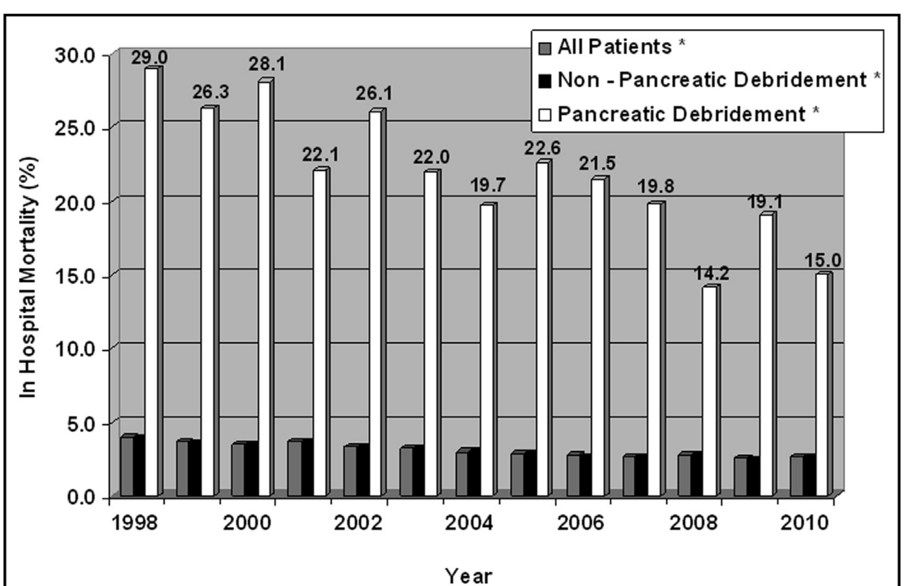

Figure 2 Acute pancreatitis patient in-hospital mortality rate by year. * $P < .05$, significant difference between 1998 and 2010.

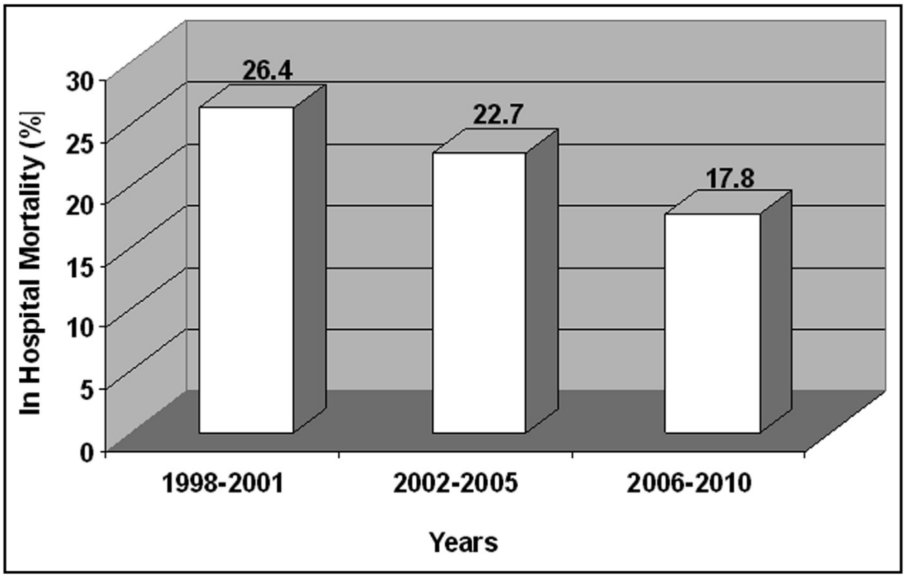

Figure 3 Pancreatic debridement patient in-hospital mortality rate by time period. * $P < .05$, significant difference between time periods.

Table 1 Demographics and AP etiology of pancreatic debridement patients

			PD patients	
	Non-PD (n = 584,195)	PD (n = 1,783)	Survival (n = 1,387)	Mortality (n = 391)
Demographic (%)				
Age (years)	53.6 ± 18.3	54.1 ± 15.6*	52.4 ± 15.5	60.4 ± 14.6†
Male	49.6	65.8*	65.1	68.0
Race				
Caucasian	65.9	77.6*	78.3	75.2†
African American	19.7	9.4*	9.2	9.8†
Hispanic	9.8	7.0*	7.0	7.0†
Other	4.6	6.0*	5.5	8.0†
Comorbidity (%)				
History of myocardial infarction	3.9	3.1	2.7	4.6
Congestive heart failure	8.2	7.8	6.7	11.8†
Chronic pulmonary disease	13.5	9.8*	9.2	12.0
Peptic ulcer disease	2.7	3.9*	3.4	5.9†
Mild liver disease	10.8	5.8*	4.8	9.5†
Moderate or severe liver disease	1.7	1.6	1.5	NR
Diabetes without complications	20.1	18.6	19.9	14.3†
Diabetes with complications	2.5	1.7*	1.8	NR
Renal insufficiency	7.2	7.1	6.1	11.0†
AIDS/HIV	1.3	NR*	NR	NR
Charlson comorbidity index	1.1 ± 1.7	.86 ± 1.3*	.8 ± 1.2	1.0 ± 1.4†
Pancreatitis etiology (%)				
Biliary	19.8	25.3*	25.0	26.1
Alcohol	14.3	9.4*	8.9	11.2
Other	20.6	15.3*	16.8	10.0†
Idiopathic	45.3	50.0*	49.3	52.7

P value is a valid reflection of actual observation.

AIDS/HIV = acquired immunodeficiency syndrome/human immunodeficiency virus; AP = acute pancreatitis; NR = not reportable to protect patient identity as observation is <10; PD = pancreatic debridement.

*$P < .05$, significant difference between non-PD and PD in univariate analysis.

†$P < .05$, significant difference between survival and mortality in univariate analysis.

Table 2 Additional procedures in pancreatic debridement patients

	Non-PD	PD	PD patients	
	(n = 584,195)	(n = 1,783)	Survival (n = 1,387)	Mortality (n = 391)
Additional procedures (%)				
Percutaneous abdominal drainage, paracentesis	1.4	15.9*	16.7	13.3
Drainage of intraperitoneal abscess	.2	10.5*	10.2	11.3
ERCP	1.3	2.3*	2.5	NR
FNA of pancreas	.2	2.4*	2.0	3.8†
Cholecystectomy‡	10.9	30.4*	31.2	27.4

ERCP = endoscopic retrograde cholangiopancreatography; FNA = fine-needle aspiration; NR = not reportable to protect patient identity as observation is <10; PD = pancreatic debridement.

*$P < .05$, significant difference between non-PD and PD in univariate analysis.

†$P < .05$, significant difference between survival and mortality in univariate analysis.

‡Includes laparoscopic, open, complete, and partial cholecystectomies.

Multivariate logistic regression utilizing the forward stepwise selection method was performed to evaluate risk factors for increased odds of mortality in patients undergoing PD. All factors in univariate analysis that were statistically different between PD patients who died and survived to discharge were utilized for analysis. After controlling for confounding factors, multivariate logistic regression identified increased age, renal insufficiency, mild liver disease, peptic ulcer disease, sepsis with organ failure, and transfer status as factors associated with increased odds of mortality in patients undergoing PD (Table 5).

Comments

The goal of this study was to evaluate national outcomes of patients with AP who undergo PD and determine factors associated with increased mortality utilizing a large national database. This study demonstrates that PD is performed in a very small subset (.3%) of all nonelective patient admissions for AP and is associated with a significant mortality (22%), LOS (46 days), and total hospitalization charge ($281,000). PD is predominantly performed in large, urban, teaching hospitals. In patients with AP who undergo PD, multivariate logistic regression identified factors associated with increased odds of mortality as increased age, renal insufficiency, liver disease, peptic ulcer disease, sepsis with organ failure, and transfer status.

In the last 20 years, mortality associated with PD has decreased, ranging from 4% to 27%.[7–9] This rate is similar to the overall mortality of 22% observed in this study. Similar to the findings in this analysis, a male predominance in patients with AP undergoing PD has been reported in the literature.[12,22–24] Etiology of AP in patients undergoing operative intervention differs between studies citing a predominance of alcohol-related[23,24] or biliary or unknown causes[25–27] similar to the findings in this study. An AP etiology subtyping methodology previously described for the NIS[16] was used in this analysis and identified a large proportion of PD patients who were typed as idiopathic, with an unknown reason for AP, which is partly limited by the coding methodology of the NIS. The extended LOS attributed to the complicated hospitalization of these patients is reported with averages of 37 to 46 days in the literature[14,22,23]; this is similar to the 46 days found in this study. A consequence of the extensive care and complicated LOS, which has not been previously addressed in the literature, is the tremendous cost of hospitalization found in this study. Patients undergoing PD had an average total hospital charge of $281,000. Additionally, only 22.2% of PD patients underwent routine discharge, with the vast majority of survivors requiring disposition to another type of facility or home health care, which would add substantially to the overall cost of care for these patients. The financial impact of patients requiring surgical intervention for AP and the healthcare dollars spent after discharge are important aspects to acknowledge in the current era of healthcare cost-containment.

This study is the 1st examination of the national utilization of PD as well as in-hospital outcomes for patients undergoing PD across a significant time period. Previous national database studies have focused on outcomes of AP in general as well as surgical outcomes over a single year.[7,14,22] This large sample, derived from a nationwide database over a 13-year period, provides a contemporary trend of operative incidence, which is low and has decreased by half over the last decade. Studies have demonstrated that severe AP, based on the 2012 revision of Atlanta classification of AP,[28] occurs in 10% to 20% of patients with AP[23] and these patients often undergo operative intervention. However, no contemporary analysis of the incidence of PD in all AP patients has been reported. Additionally, these results demonstrate that the longitudinal trend in mortality has decreased for all AP patients, including those treated nonoperatively, which has been reduced from approximately 4% to 3%. Additionally, over the 13-year study period, the mortality rate in AP patients undergoing PD in the United States has decreased considerably from 29% to 15%.

A single-center trend in mortality was cited by Rau et al,[11] evaluating those undergoing operative treatment

Table 3 Hospitalization characteristics of pancreatic debridement patients

	Non-PD (n = 584,195)	PD (n = 1,783)	PD patients: Survival (n = 1,387)	PD patients: Mortality (n = 391)
Admission on weekend (%)	26.4	24.4	24.7	23.2
Transfer (%)	3.4	25.7*	24.3	30.1†
Length of stay (days)	6.3 ± 8.4	46.2 ± 37.6*	47.6 ± 37.2	41.1 ± 38.3†
Mean total charges ($) ± standard deviation	28,333.08 ± 54,894.57	281,300.70 ± 249,996.98*	275,359.90 ± 249,329.41	301,493.15 ± 314,610.38†
Disposition (%)				
Routine	77.2	22.2*		
Short-term hospital	3.1	3.4*		
Another type of facility	8.4	29.2*		
Home health care	5.4	23.1*		
Against medical advice	2.8	NR*		
Died in hospital	3.1	22.0*		
Mortality (%)	3.1	22.0*		

P value is a valid reflection of actual observation.
NR = not reportable to protect patient identity as observation is < 10; PD = pancreatic debridement.
*$P < .05$, significant difference between non-PD and PD in univariate analysis.
†$P < .05$, significant difference between survival and mortality in univariate analysis.

between 1982 and 1993 compared with 1993 and 2001; however, they found an increase trend in mortality, which they attributed to increased overall perioperative disease and organ failure. Similarly, Howard et al reviewed 102 consecutive patients undergoing PD at a single center from 1993 to 2005 and found a significant decrease in operative mortality (18% from 1993 to 2001 vs 4% from 2002 to 2005).[8] In a contemporary single-year (2007) analysis of a national database, Parikh et al[7] utilized the American College of Surgeons National Surgical Quality Improvement Program database to evaluate outcomes of patients undergoing PD and found a 30-day mortality of 6.8%. A benefit of the NIS is that it includes all types of nonfederal hospitals, reducing the single-center tertiary and referral center bias to give a more inclusive analysis of national outcomes and data are available over a broad time period to allow for analysis of trends in utilization of care and outcomes.

When evaluating hospital characteristics of AP admissions in the United States, the majority of PD was performed at large, teaching hospitals in urban areas of high median income by zip code. Although most literature evaluating operative intervention in AP arises from series reported by large, urban, university hospital systems,[4,5,24,26] no study to date has evaluated the distribution of this operation among different regions and hospital types in the United States and its association with survival. This study demonstrates a predilection toward operative treatment in the Northeast compared with the South and in patients with private insurance as opposed to self-payers. Interestingly though, when comparing patients undergoing PD who died and those who survived to discharge, there was no association with hospital bed size, teaching status, urban location, region of the country, or median household income by zip code. Mortality was associated with Medicare payer status, which one would expect with an elderly population; indeed, we noted that older age was a predictor of mortality.

Patients undergoing PD are often referred to larger institutions. In this study, 25.7% were transferred patients as opposed to 3.4% of those treated nonoperatively. Transfer status has been evaluated in prior studies, as demonstrated by the 70% transfer rate of patients evaluated in a single-center review of surgical debridement at Massachusetts General Hospital.[26] The rate found in this analysis is closer to that reported by Gotzinger et al[5] (35%) and Parikh et al[7] (42%). Patient transfer has also been found to be prognostic of outcomes in patients with severe pancreatitis. Halonen et al[24] found that mortality rate was 10-fold higher in patients referred from another hospital and it was associated with a worse prognosis, recommending emergency transfer for patients with severe AP to a hospital with expertise in treatment of complications of the disease as well as timing for surgical intervention. In patients undergoing PD in this study, those who were transferred had a higher rate of mortality (27.5% vs 22%; $P = .0375$), despite the similar rate of sepsis with organ failure between transferred and nontransferred admissions (12.5% vs 14.4%; $P = .3576$.); although mortality was higher, the difference was not as severe. Although

Table 4 Regionalization of pancreatic debridement patients

	Non-PD (n = 584,195)	PD (n = 1,783)	PD patients Survival (n = 1,387)	PD patients Mortality (n = 391)
Hospital bed size (%)				
Small	14.1	5.6*	5.3	6.7
Medium	27.3	19.7*	20.0	18.3
Large	58.6	74.7*	74.7	75.0
Teaching status (%)	38.3	69.9*	69.4	71.4
Urban (%)	81.7	94.2*	94.0	95.1
Region (%)				
Northeast	18.5	24.4*	23.4	28.1
Midwest	23.7	24.8*	25.7	22.3
South	48.0	39.5*	38.9	40.9
West	9.8	11.3*	12.0	8.7
Primary payer (%)				
Medicare	34.9	33.3*	28.8	49.1†
Medicaid	13.9	12.9*	13.8	9.5†
Private, including HMO	34.4	43.3*	45.8	34.5†
Self-pay	12.1	6.0*	6.6	3.8†
Other	4.7	4.5*	5.0	3.1†
Median household income (%)‡				
\$1–\$24,999	24.7	18.7*	19.0	17.6
\$25,000–\$34,999	28.6	27.1*	27.1	27.4
\$35,000–\$44,999	24.4	25.8*	26.6	22.9
\$45,000 and above	22.3	28.4*	27.3	32.1

HMO = health maintenance organization; PD = pancreatic debridement.
*$P < .05$, significant difference between non-PD and PD in univariate analysis.
†$P < .05$, significant difference between survival and mortality in univariate analysis.
‡Median household income is based on patient zip code.

unsubstantiated, this observation would suggest that patients who are transferred are in some way more critically ill or that the timing or mode of transportation was in some way detrimental in and of itself. The rate of transfer throughout the study period was analyzed and no significant trend was found between the study years.

After controlling for confounding factors in patients undergoing PD in this study, multivariate logistic regression identified increased mortality to be associated with increased age, renal insufficiency, mild liver disease, peptic ulcer disease, sepsis with organ failure, and transfer status. In a series of 250 patients with AP who underwent operative treatment by Gotzinger et al,[5] age, multiple organ failure, Acute Physiology and Chronic Health Evaluation II score at admission, and infection of necrosis were all associated with increased mortality. Additionally, AP etiology was not prognostic of mortality, which is similar to the findings in this study.[5] Higher rates of sepsis with organ failure was found in patients who died after PD in this study, which is consistent with the literature demonstrating that the presence of organ failure[29] is prognostic of mortality in patients with AP.[9,30] Certainly, the trends in utilization of percutaneous and minimally invasive drainage procedures have contributed to the decrease in mortality of PD, which corresponds to the near doubling of incidence in use over the last decade (12.1% to 20.3%) as seen in this study. Interestingly, peptic ulcer disease was found to be associated with increased mortality in patients undergoing PD. Studies have demonstrated that patients suffering from AP are at risk of peptic ulcer disease and it is associated with severe AP based on Acute Physiology and Chronic Health Evaluation II score.[31]

This dataset from the NIS provides powerful trends in health care and outcomes but with inherent constraints and limitations that likely impact the ability to draw certain conclusions. It only captures inpatient data and does not allow the evaluation of outpatient survival and morbidity,

Table 5 Factors associated with increased odds of mortality in acute pancreatitis patients undergoing pancreatic debridement*

Factor	Odds ratio	Confidence interval†	P value
Age‡	1.04	1.03–1.05	<.01
Sepsis with organ failure	1.76	1.24–2.51	<.01
Peptic ulcer disease	1.83	1.02–3.30	<.05
Mild liver disease	2.27	1.36–3.78	<.01
Renal insufficiency	1.78	1.14–2.78	<.05
Received as transfer	1.44	1.08–1.93	<.05

*Factors identified by multivariate logistic regression utilizing the stepwise forward selection method.
†All odds ratios calculated with a 95% confidence interval.
‡Increase odds for a 1-year difference only and not per year.

which is important in this study of complex patients with a high risk for complications and the inherent risks of this disease such as problems from pancreatic duct strictures, chronic fistulas, recurrent pancreatitis, and walled-off pancreatic necrosis/pancreatic pseudocyst.[32] Additionally, determining if patients in the NIS are readmitted is unavailable and thus the sample of patients undergoing PD likely contains an unknown number of patients requiring additional hospitalization for various reasons. Also, patients with AP not undergoing surgery may be discharged and later readmitted under the umbrella coding of "AP," during which admission they may undergo debridement. These patients are counted in the database as new admissions and constitute an unknown portion of the dataset. This limits the ability to comment on the timing of initial operative intervention, which is an important point in the management of pancreatic necrosis and cannot be concluded from this dataset.

When evaluating the data source, a limitation is that it is based on ICD-9-CM/PR coding, which lacks subcoding for necrosis (infected or sterile), which is an important factor in helping to determine operative indication and prognosis for comparison. The NIS also lacks a temporal association of the diagnosis code during the hospitalization, which prevents knowing physiologic parameters before surgery and whether sepsis with organ failure happened before or after their initial PD. The number of PDs a patient underwent or the extent of debridement performed was unable to be determined, which is a valuable information when up to 74% of patients require reoperation.[5] Furthermore, how the PD was performed is unavailable; such techniques as open packing,[30] closed packing,[26] closed lavage,[4] or newer minimally invasive laparoscopic transgastric or retroperitoneal[33] or endoscopic transgastric approaches[32] were unable to be stratified because of the lack of specific procedure codes in the NIS. Once specific procedure codes are available, large database studies may reveal trends in PD-type utilization and its effect on surgical outcomes and mortality. Despite the limitations of the study, this study provides a contemporary analysis of PD within the United States.

In conclusion, with the 1st national evaluation of surgical outcomes in AP over greater than a decade, this study has demonstrated that those who undergo PD have high inpatient mortality, LOS, total charge of hospitalization, and are regionalized to large, urban, teaching hospitals. In the United States, the incidence of PD in patients with AP is low and has decreased to half over the last decade with a decreasing trend in mortality. In patients with AP who undergo PD, multivariate logistic regression identified factors associated with increased odds of mortality as older age, renal insufficiency, liver disease, peptic ulcer disease, sepsis with organ failure, and transfer status.

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Appendix A Acute pancreatitis etiology subtyping*

Subtype	ICD-9-CM and/or ICD-9-PR codes
Biliary	
Biliary-related codes	574, 575.0, 575.1, and 576
Alcohol	
Alcohol-related codes	291, 303, 305.0, 357.5, 425.5, 571.0, 571.0, 571.1, 571.2, 571.3, 980.0, and V11.3
Other	
HIV	042
Viral hepatitis	070
Mumps	072
Systemic lupus	710.0
Systemic rheumatic disease	714.0
ERCP	51.10, 51.11, 51.13, and 51.85
Hyperlipidemia	272
Hyperparathyroidism	252.0
ESRD	585.6
Trauma	860–869
Pancreatic divisum	577.8
Other†	790.5
Idiopathic	
All remaining patients‡	

ERCP = endoscopic retrograde cholangiopancreatography; ESRD = end-stage renal disease; HIV = human immunodeficiency virus; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-9-PR = International Classification of Diseases, Ninth Revision, Procedure Related.

*Subtyping derived from Chen et al.[16]

†Other ICD-9-CM code defined as "nonspecific abnormal serum amylase and lipase levels."

‡Patients were stratified into biliary, alcohol, or other subtype in order by coding to create mutually exclusive groups; all remaining patients were classified as idiopathic.

Appendix B Postoperative in-hospital complications*

Complications	ICD-9-CM codes
Mechanical wound complications	
Delayed wound healing	998.83
Postoperative hematoma	998.12
Postoperative seroma (noninfected)	998.13
Disruption of operative wound	998.3
Persistent postoperative fistula	998.6
Infections	
Postoperative infection	998.5
Postoperative skin abscess	998.59
Postoperative septic wound complications	998.59
Postoperative skin infection	998.59
Postoperative intra-abdominal abscess	998.59
Postoperative subdiaphragmatic abscess	998.59
Postoperative infected seroma	998.51
Urinary complications	
Postoperative urinary retention	997.5
Postoperative urinary tract infection	997.5
Pulmonary complications	
Postoperative atelectasis	997.3
Postoperative pneumonia	997.3
Mendelson syndrome resulting from a procedure	997.3
Postoperative acute respiratory insufficiency	518.5
Postoperative acute pneumothorax	512.1
Postoperative ARDS	518.5
Postoperative pulmonary edema	518.4
Gastrointestinal complications	
Postoperative small bowel obstruction	997.4
Postoperative ileus	997.4
Postoperative ileus requiring nasogastric tube	997.4
Postoperative nausea	997.4
Postoperative vomiting	997.4
Postoperative pancreatitis	997.4
Complication of anastomosis of GI tract	997.4
Cardiovascular complications	
Postoperative deep venous thrombosis	997.79
Postoperative pulmonary embolism	415.11
Postoperative stroke	997.02
Phlebitis or thrombophlebitis from procedure	997.2
Cardiac arrest/insufficiency during or resulting from a procedure	997.1
Systemic complications	
Postoperative shock (septic, hypovolemic)	998.0
Postoperative fever	998.89
Complications during procedure	
Accidental puncture or laceration, complicating surgery	998.2
Foreign body accidentally left during procedure	998.4
Bleeding complicating procedure	998.11

ARDS = adult respiratory distress syndrome; GI = gastrointestinal; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification.

*Complication coding derived from Guller et al.[17]

Appendix C Additional procedure coding

Procedure/Diagnosis	ICD-9-CM and/or ICD-9-PR codes
Procedures	
Percutaneous abdominal drainage, paracentesis	54.91
Drainage of intraperitoneal abscess	54.19
ERCP	52.13, 51.11, and 51.10
FNA of pancreas	52.11
Cholecystectomy*	51.21, 51.22, 51.23, and 51.24

ERCP = endoscopic retrograde cholangiopancreatography; FNA = fine-needle aspiration; ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-9-PR = International Classification of Diseases, Ninth Revision, Procedure Related.

*Includes laparoscopic, open, complete, and partial cholecystectomies.