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Improved Perioperative Outcomes With Minimally Invasive Distal Pancreatectomy:

Results From a Population-Based Analysis

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Abstract

IMPORTANCE—Interest in minimally invasive distal pancreatectomy (MIDP) has grown in recent years, but currently available data are limited. Greater insight into application patterns and outcomes may begained from a national database inquiry

OBJECTIVES—To study trends in the use of MIDP and compare the short-term outcomes of MlDPwith those of open distal pancreatectomy.

DESIGN, SETTING, AND PARTICIPANTS—Population-based retrospective cohort study evaluating perioperative outcomes and hospital charge measures for distal pancreatectomy, comparing the surgical approaches and adjusting for patient- and hospital-level factors, among patients undergoing elective distal pancreatectomy from 1998 to 2009 in the Nationwide Inpatient Sample in a 20% stratified sample of all US hospitals

MAIN OUTCOMES AND MEASURES—In-hospital mortality, rates of perioperative complications and splenectomy, total charges, and length of stay.

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RESULTS—A total of 8957 distal pancreatectomies were included in this analysis, of which 382 (4 3%) were MIDPs. On a national level, this projected to 42 320 open distal pancreatectomies and 1908 MlDPs. The proportion of distal pancreatectomies performed via minimally invasive approaches tripled between 1998 and 2009, from 2 4% to 7.3%. The groups were comparable for sex and comorbidity profiles, while patients who underwent MlDPwere 15 years older. On multivariate analysis. MIDP was associated with lower rates of overall predischarge complications, including lower incidences of postoperative infections and bleeding complications, as well as a shorter length of stay by 1.22 days There were no differences in rates of in-hospital mortality, concomitant splenectomy, or total charges

CONCLUSIONS AND RELEVANCE—This population-based study of MlDP reveals that the application of this approach has tripled in practice and provides strong evidence that MIDP has evolved into a safe option in the treatment of benign and malignant pancreatic diseases.

As laparoscopic instruments have become more refined and advancements in robotic platforms have allowed for improved ergonomics and more controlled movements, the applications of minimally invasive surgery have greatly expanded. The evolution of minimally invasive pancreatic surgery, however, has been relatively slow in gaining traction. Indeed, while the first reports of laparoscopic pancreatic surgery were published in 1994,[1-3] the vast majority of the literature on this topic has been published in only the past 5 to 10 years and consists primarily of single-institution/ surgeon experiences,[4-9] multi-institutional case series,[10-13] and meta-analyses based thereupon.[14-17] This delay in the wide-spread adoption of minimally invasive techniques in the treatment of pancreatic disease was likely engendered, at least in part, by the inherent technical challenges presented by the retroperitoneal location and notoriously unforgiving nature of the pancreas, close proximity to major vascular structures, and early concerns regarding oncologic outcomes.[13,18] While results from existing series are promising, they have been limited in their generalizability and interpretation by their sample size and variable practice setting. A broader investigation into this topic is therefore warranted.

The aims of our study were to gain insight into the national application of minimally invasive techniques in the treatment of left-sided pancreatic lesions and to examine comprehensive patient safety outcome analyses using a nationwide database of inpatient hospital stays. Specifically, we sought to compare the outcomes of minimally invasive distal pancreatectomy (MIDP) with those of open distal pancreatectomy (ODP), focusing on the following 5 perioperative outcomes: rates of in-hospital mortality, overall perioperative complications, concomitant splenectomy, length of stay (LOS), and hospital charges.

Methods

Retrospective analysis of the US Nationwide Inpatient Sample (NIS) database was performed for a 12-year period from January 1, 1998, through December 31, 2009. Created and operated by the Agency for Healthcare Research and Quality, the NIS is the largest all-payer inpatient database in the United States and consists of a 20% stratified sample of inpatient discharges from more than 1050 hospitals in 44 states as of 2009.[19] Thus, it covers 95% of the US population. Weighted sampling allows estimates for national trends to be achieved. The NIS provides more than 100 clinical and nonclinical data variables from each hospital stay, including primary and secondary diagnoses and procedures, admission and discharge types, patient demographic characteristics (age, sex, Charlson Comorbidity Index, etc), insurance type, total charges, LOS, and hospital characteristics. While laparoscopic procedure codes were available for the entire study period, robotic procedure codes became available only beginning in October 2008. This analysis of a nationwide database is not subject to institutional review board approval and does not involve patient participation, thereby negating the need for informed consent.

All discharges from 1998 through 2009 with a procedure code for distal pancreatectomy (DP) were identified using principal or secondary procedure International Classification of Diseases, Ninth Revision, Clinical Modification codes 52.52 and 52.59. Concurrent application of procedure codes 54.21 and 17.42 identified laparoscopic and laparoscopic-assisted robotic approaches, respectively. Patients younger than 18 years were excluded from our study, as were all admissions classified as nonelective. Indications for surgery were grouped into 3 categories based on diagnostic codes: benign conditions, including benign neoplastic processes; pancreatitis (acute and chronic); and malignant conditions. Complication categories were created by combining individual diagnostic codes, as well as procedure codes serving as surrogate markers for complications, into 5 main groups: overall infectious complications (diagnoses: postoperative infection, abscess, sepsis; procedure: percutaneous drain placement); wound complications (diagnoses: persistent postoperative fistula, nonhealing surgical wound, wound disruption or dehiscence, seroma); bleeding complications (diagnoses: hemorrhage, hematoma; procedures: transfusion of whole blood, packed red blood cells, platelets, or plasma); end-organ dysfunctions (diagnoses: cardiac, respiratory, digestive, and urinary system complications; procedures: continuous invasive mechanical ventilation for ≥96 hours, hemodialysis); and thromboembolic complications (diagnoses: venous embolism and deep venous thrombosis, pulmonary embolism and infarction). Additionally, the rate of accidental injuries at the time of surgery, defined by diagnostic code 998.2 (accidental puncture or laceration during a procedure), was also assessed for all procedures and included in our analysis of overall perioperative complications. Concomitant splenectomy was identified using the primary or secondary procedure code 41.5.

The annual prevalences of MIDP and ODP from 1998 through 2009 were examined to assess application trends. Patients were grouped by surgical approach, with their demographic factors, hospital setting, and indications for surgery being compared. Univariate tests, using χ^2 test, *t* test, and Fisher exact test, were performed to examine differences in the inhospital mortality rates, complication rates, LOS, total hospital charges, and rates of concomitant splenectomy. Multivariate analyses were conducted to assess these same outcomes, controlling for age, sex, race, Charlson Comorbidity Index, teaching hospital status, and indication for surgery. The Charlson Comorbidity Index is a measure of comorbidities based on the presence or absence of certain diagnoses in the patient. These are then combined in a weighted formula.[20] Statistical analysis was performed using Stata version 11.1 statistical software (StataCorp LP), with statistical significance set at $P \leq .05$.

Results

From 1998 through 2009, 8957 DPs were reported in the NIS that met our inclusion criteria, projecting to an estimated 44 228 DPs nationwide. Of these, 382 (4.3%) were performed in a minimally invasive approach. During this period, the number of both ODPs and MIDPs increased, with a greater relative rise in the prevalence of MIDPs. The proportion of all DPs performed minimally invasively tripled from 2.4% in 1998 to 7.3% in 2009 (Figure). This projected to a total of 1908 MIDPs during this time, with more than 1000 of those cases having been performed in the last 3 years of the study period.

Compared with patients undergoing ODP, those who underwent MIDP were older (mean age, 58.3 vs 60.7 years; $P = .002$) and more likely to have undergone surgery at a teaching institution (73.4% vs 85.6%; $P < .001$). Furthermore, they were more likely to have undergone surgery for malignant conditions and less likely for pancreatitis than their counterparts who underwent ODP (malignant conditions, 36.6% vs 28.2%; pancreatitis, 17.2% vs 26.2%; and benign conditions, 46.2% vs 45.6%; $P < .001$). There were no differences in the sex, race, or comorbidity profiles of the 2 groups (Table 1).

On unadjusted analysis (Table 2), the MIDP group compared with the ODP group had LOS reduced by 2 days ($P < .001$) and a lower overall complication rate (30.1% vs 39.0%; $P < .001$). This difference in overall complications was mainly driven by a lower rate of bleeding complications (13.1% vs 20.6%, $P < .001$), as evidenced by a lower rate of transfusion of packed red blood cells (11.3% vs 18.0%; $P = .001$). There were no differences in the in-hospital mortality rates ($P = .06$) or total charges ($P = .10$). A higher rate of concomitant splenectomy was found in the MIDP group than in the ODP group (81.7% vs 75.7%; $P = .007$).

After adjusting for age, sex, race, Charlson Comorbidity Index score, hospital teaching status, and surgical indications in multivariate analyses (Table 3), MIDP was found to be associated witha 1.22-day reduction in LOS (95% CI, −2.42 to −0.02; $P = .046$). There was no difference in the in-hospital mortality rate ($P = .12$) or total hospital charges ($P = .60$), but there was a 25% reduction in the overall complication rate (odds ratio [OR] = 0.75; 95% CI, 0.58 to 0.98; $P = .04$). When analyzing the 5 complication categories individually, bleeding complications were significantly reduced in the MIDP group (OR = 0.65; 95% CI, 0.46 to 0.93; $P = .02$). The postoperative infection rate was also significantly lower in the MIDP group (OR = 0.29; 95% CI, 0.09 to 0.91; $P = .03$), with a trend toward better outcomes in the overall infectious complication category for patients under inglVllDP(OR = 0.59; 95%CI,o.33tol.07;P = .08).There was nodifference in the rate ofaccidental injury oneither univariate ($P = .34$) or multivariate ($P = .79$) analysis. The splenectomy ratedid not significantly differ between the 2 groups on multivariate analysis ($P = .08$).

Table 4 examines allcovariates independently for the outcomes of interest. Surgery performed at a teaching institution was associated with betteroutcomes for nearly everyanalyzed parameter, including rates ofin-hospital mortality, overall predischarge complications, LOS, and total charges. On the other hand, operations performed for pancreatitisand malignant conditions were both associated with worse outcomes than those performed for benign indications. Only malignant indications, however, were associated witha higher rate ofconcomitant splenectomy (OR= 2.66; 95%Cl,2.25-3.15;*P* < .001).

Discussion

The emergence oflaparoscopic and robotic technologies during the past few decades has radically changed the surgical landscape. Minimally invasive approaches have been shown to result in reduced postoperative pain and inflammation as well as more rapid recovery compared with their open counterparts across a variety ofprocedures.[21,22]

In the case of DP, initial series describing the laparoscopic approach have yielded encouraging results and prompted more recent comparative, but still retrospective, case seriesand multi-institutional studies. Toour knowledge, this report represents the largest analysisof outcomesoflVIIDPfrom a nationally representative population database in the United States. In this study, we used the NIS to gain a broader understanding of the comparative outcomes of MID P and 0DP. In contrast toa recently published study[23] that used the NIS and 2 other national patient care databases to investigate trends in DPfor neoplastic processes, we alsostudied pancreatitis and other benign indications. Furthermore, we limited the procedure codes to minimize the possible inclusion of enucleations and pancreaticoduodenectomies. Finally, we also included the code for robotic procedures. It bears emphasizing that while robotic procedures were included inour study, they accounted foronly 5.5%ofall IVI IDPsowing to the limited time during which they became identifiable and their relative overall infrequency. For thepurposesofthisstudy, wechosetofocus on inpatient outcomes, including in-hospital mortality rates, perioperativecomplication rates, hospital LOS, and total charges. In addition to these parameters, we used the NIS database to assess the pattern of MIDP performance during the study period.

From 1998 through 2009, 8957 DPs were recorded in the NIS database, projecting to more than 44 ooo cases nationwide. While MIDPs represented only 4.3%ofthis total, with 382Curnulative cases projecting to 1908estimated cases nationwide, the practice of MIDP has tripled during this time, reaching 7.3%ofall DPs in 2009. Infact, more thanhalfof all recorded MIDPs were performed in the final 3years of the study period. Still, there likely remained a strong selection bias for this approach, as illustrated by a significantly smaller proportionof MIDPs than ODPs performed for pancreatitis, which was associated with significantly worse outcomes. Conversely, a greater proportion of MID Ps in this database were performed for malignant conditions, which also bore anassociation with worse outcomes. Because the N IS database does not include important oncologic parameters such as tumor size, disease stage, or margin status, any comparison of surgical outcomes strictly between MID Pand ODPfor this subset of patients would be incomplete.

In this large population-based analysis comparing MIDP with 0DP, we observed improved outcomes in the MID Pgroup. These were namely a 25% reduction in the rate of overall immediate perioperative complications (30.1% vs 39.0%), highlighted by lower rates of postoperative infection (2.9% VS 4.7%) and bleeding complications (13.1% vs 20.6%), as well asashortened LOS. There was no statistically significant difference in the in-hospital mortality rates, the incidence of accidental injuries, or the rate of concomitant splenectomy between the 2 approaches. Our findingsare consistent with those from a recent comprehensive meta-analysisoflaparoscopic DP (LDP) compared with ODP by Venkat et al,[14] who reported a lower incidence of overall morbidity (33.9% vs 44.2%), including lower rates of surgical site infections (2.9% vs 8.1%) and fewer transfusion requirements (1.7% vs 11.6%),as well asa 4.0-day reduction in LOS with LDP. The markedly greater reduction in LOS with LOP reported in the meta-analysis compared with our study (4.0vs 1.22 days)maybeskewed by its inclusion of several studies with unusually long hospital stays in the ODParm (mean LOS, 16-27 days). By contrast, large comparative series from major American centers have reported benefits of LOS reduction ranging from 1 to 3.1 days.[5,10,24] Also, it is worth noting that our reported rates of postoperative infections for both MIDP and ODP appeared relatively low compared with published data; this can be attributed toour decision tostrictly includeonly those diagnostic codes that clearly identified postoperative infections, thus excluding infections that may have been otherwise classified.

Currently available cost-effectiveness analyses for MIDP can be difficult to interpret and may not be generalizable, as they originate from different countries and therefore reflect the inherent variability in health care systems and practices. [8,25,26] Furthermore, owing to the relative infancy of the robotic experience, little cost information is available for this subset of MIDP. Waters et al[27] did compare costs for robotic DP, LDP, and ODPand demonstrated nodifferencein total hospital costs between these 3approachesdespite-and likely as a result of–a significantly shorter LOS in the robotic DPcohort compared with the LPDand OPD groups (4 vs 6 vs 8 days). This study did not, however, adjust for the difference in indications for surgery between the 3groups. Analyzing total hospital charges rather than costs (the former reflects the cost to the patient; the latter, that to the hospital) and after correcting for surgical indications, we also found that there was no significant difference between MIDP and ODP from a costeffectiveness standpoint. This financial equipoise is likely achieved because the higher operative costs of the minimally invasive approaches (le, pricier instruments and equipment) are offset by the reduced LOS they afford. It is important to point out that the need toadjust for surgical indications isgreat when comparing MIDP and ODP, as our study indicates that malignant conditions and especially pancreatitis were independent predictors of not just higher total charges but also greater LOS and higher morbidity and mortality rates. Additionally, surgery performed at a teaching hospital, irrespective of the approach, was strongly associated with betterover - alloutcomes, including lower ratesofin-hospital mortality and overall complications, shorter LOS, and lower total charges.

Inaddition tosurgical outcomes, our studyalso sought to highlight the use of lVI IDP overtime. The diffusion of innovation into general practice isa worthwhile framework in which toevaluate the adoption ofnovel technology. Toward this end, Barkun et al[28] have described a s-stage model that includes innovation, development, exploration, assessment, and long term. Based on their criteria, IVIIDPsare likely in theearlystages of exploration, in which many ofthe technical detailsof these procedures have been perfected, and although still novel, existing evidence suggests they are safe. Still, minimally invasive approaches to DP demand a great level of technical skill and present a stiff learning curve, as suggested by the nonequivalent outcomes achieved at teaching and nonteaching facilities. As the application of MIDP becomes more widespread and early adopters transition into the early majority,[29] it is likely that these differences will disappear and the full benefits of MIDP may be realized.

Our study's main strength lies in the large analytic cohort that is a sampling of 20% of all hospitals in the United States weighted in such a way as to permit estimation of national trends. Conversely, there are a number of inherent limitations to this study that must be taken into account. First, the current International Classification of Diseases, Ninth Revision coding system, on which the NIS is based, requires the colisting of codes 54.21 and 17.42 with the primary open procedure codes to capture their laparoscopic and laparoscopic-assisted robotic counterparts, respectively. However, these codes generally fail to capture all minimally invasive procedures, as surgeons and medical coders may have resorted to using the unlisted procedure codes instead. Therefore, while codes 54.21 and 17.42 permit specific selection of MIDP in our study, their sensitivity in identifying all MIDPs is unknown and likely underestimates the MIDP experience. Next, pancreatic fistulas represent a major surgical outcome of interest when discussing pancreatic operations. However, owing to the limitations of the NIS coding system, we were unable to isolate this complication for analysis. Current studies suggest no difference in the incidence of either clinically significant or overall pancreatic fistulas between LDP and ODP.[14] A third limitation of the NIS database rests in its lack of patientspecific oncologic data such as tumor size, tumor stage, or margin status, which prevented us from performing any direct comparative subset analysis for patients with malignant indications for DP. A multicenter study by Kooby et al[13] in 2010 reported equivalent oncologic outcomes between LDP and ODP for patients with malignant conditions; in particular, there were no differences in margin-positive rates, lymph node yield, or overall survival. These patients had previously been included in a separate report in which the authors, in a comparative analysis matching for age, American Society of Anesthesiologists score, tumor size, type, and diagnosis, reported no difference in mortality but lower rates of complications and shorter hospital stays.[10] Finally, although large administrative databases like the NIS are inherently susceptible to coding discrepancies, such errors are unlikely to produce differential biases, as they would be random and evenly distributed across groups. Likewise, while a number of developments have come about during our study period that have improved surgical outcomes, including the introduction of clinical pathways and the establishment of quality care initiatives such as perioperative antibiotic administration, these changes alone cannot be responsible for the differences highlighted herein, as they would affect the ODP and MIDP groups equally.

Conclusions

Our study supports the findings from earlier series that minimally invasive approaches to DP are associated with an improved complication profile, with lower rates of postoperative infection and bleeding complications as well as a shorter hospital LOS compared with the open approach, at least in the immediate perioperative period. There were no differences in the in-hospital mortality rates, the incidences of accidental injury, concomitant splenectomy, or total hospital charges. As the adoption of MIDP becomes more widespread, future studies are needed to assess the long-term outcomes of these techniques, especially with regard to oncologic outcomes.

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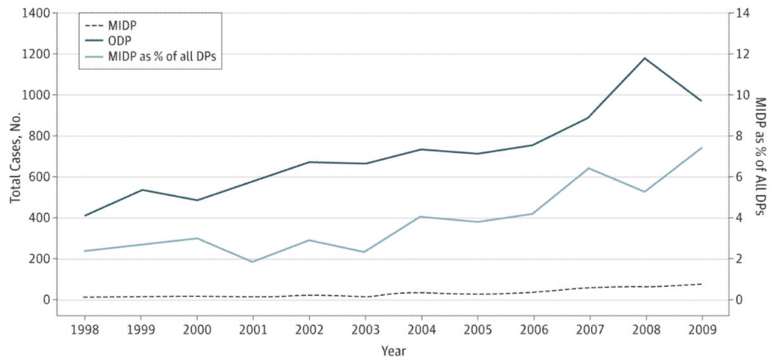

Figure.

Trends in Distal Pancreatectomy (DP) Performance From 1998 to 2009 in the Nationwide Inpatient Sample Database

While the numbers of open DP (ODP) and minimally invasive DP (MIDP) increased through the years, the performance of MIDP as a percentage of all DPs tripled during this period, from 2.4% to 7.3% of all DPs.

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Table 1

Demographic Characteristics of Patients Undergoing Open and Minimally Invasive Distal Pancreatectomy

Characteristic	% ODP (n = 8575)	% MIDP (n = 382)	*P* Value
Age, mean (SE), y	58.3 (0.2)	60.7 (0.8)	.002
Female	56.9	60.2	.20
Race			
White	58.0	60.0	
Black	7.2	4.7	.19
Other	34.8	35.3	
Charlson Comorbidity Index score >2	64.6	60.7	.12
Teaching hospital	73.4	85.6	<.001
Indication for surgery			
Benign conditions[a]	45.6	46.2	
Pancreatitis	26.2	17.2	<.001
alignant conditions	28.2	36.6	

Abbreviations: MIDP,minimally invasive distal pancreatectomy; ODP, open distal pancreatectomy.

[a]Excluding pancreatitis.

Table 2

Unadjusted Analysis of Outcomes of Open and Minimally Invasive Distal Pancreatectomy

Outcome	ODP (n = 8575)	MIDP (n = 382)	*P* Value
Length of stay, mean (SE), d	10.76 (0.13)	8.62 (0.42)	<.001
Total charges, mean (SE), *$*	80 519 (1231)	70 875 (3896)	.10
In-hospital mortality rate, *%*	3.1	1.0	.06
Overall perioperative complication rate, *%*	39.0	30.1	<.001
Overall infections	8.2	5.8	.09
Postoperative infections	4.7	2.9	.10
Wound complications	1.6	1.3	.71
Bleeding complications	20.6	13.1	<.001
Transfusion of packed RBCs	18.0	11.3	.001
Organ dysfunction	17.8	15.2	.19
Thromboembolic complications	0.9	0.5	.41
Accidental injury, *%*	3.8	2.9	.34
Splenectomy, *%*	75.7	81.7	.007

Abbreviations: MIDP, minimally invasive distal pancreatectomy; ODP, open distal pancreatectomy; RBCs, red blood cells.

Table 3

Multivariate Analysis of Outcomes for Minimally Invasive Distal Pancreatectomy Compared With Open Distal Pancreatectomy

Outcome	Net Difference or OR (95% CI)[a]	*P* Value
Length of stay, d	−1.22 (−2.42 to −0.02)	.046
Total charges, $	−2888 (−13 596 to 7820)	.60
In-hospital mortality rate	0.33 (0.08 to 1.34)	.12
Overall perioperative complication rate	0.75 (0.58 to 0.98)	.04
Overall infections	0.59 (0.33 to 1.07)	.08
Postoperative infections	0.29 (0.09 to 0.91)	.03
Wound complications	0.81 (0.25 to 2.60)	.72
Bleeding complications	0.65 (0.46 to 0.93)	.02
Transfusion of packed RBCs	0.71 (0.49 to 1.03)	.07
Organ dysfunction	0.94 (0.66 to 1.32)	.70
Thromboembolic complications	0.90 (0.21 to 3.77)	.88
Accidental injury	0.90 (0.44 to 1.86)	.79
Splenectomy	1.31 (0.96 to 1.77)	.08

Abbreviations: OR, odds ratio; RBCs, red blood cells.

[a]Values for length of stay and total charges are expressed as net difference (95% CI); all others are expressed as OR (95% CI).

Table 4

Multivariate Analysis of Outcomes for Independent Variables in All Patients Undergoing Distal Pancreatectomy

	OR (95% CI)			Net Difference (95% CI)	
Variable (Reference)[a]	**Mortality**	**Complications**	**Splenectomy**	**LOS, d**	**Total Charges, $**
Age (continuous)	1.04 (1.03 to 1.06)[a]	1.01 (1.01 to 1.01)[a]	1.01 (1.00 to 1.01)[a]	0.04 (0.02 to 0.06)[a]	265 (109 to 421)[a]
Female (male)	0.83 (0.58 to 1.17)	0.85 (0.76 to 0.95)[a]	0.87 (0.77 to 0.99)[a]	−1.41 (−1.94 to −0.88)[a]	−14 044 (−18 786 to −9)[a]
Nonwhite (white)	1.23 (0.86 to 1.76)	0.92 (0.83 to 1.03)	1.03 (0.92 to 1.17)	0.004 (−0.52 to 0.52)	−3791 (−8480 to 898)
CClscore >2 (CCl score ≤2)	1.78 (1.02 to 3.11)[a]	1.30 (1.14 to 1.48)[a]	1.16 (1.00 to 1.34)[a]	0.95 (0.34 to 1.56)[a]	6779 (1286 to 12 272)[a]
Teaching hospital (nonteaching hospital)	0.59 (0.41 to 0.85)[a]	0.76 (0.67 to 0.86)[a]	0.99 (0.86 to 1.13)	−0.82 (−1.40 to −0.23)[a]	−6587 (−11 902 to −1272)[a]
Indication (benign conditions)					
Pancreatitis	3.64 (2.13 to 6.23)[a]	1.63 (1.40 to 1.89)[a]	0.99 (0.84 to 1.16)	3.66 (2.94 to 4.37)[a]	32 523 (26 079 to 38 967)[a]
Malignant conditions	2.30 (1.37 to 3.85)[a]	1.21 (1.05 to 1.38)[a]	2.66 (2.25 to 3.15)[a]	1.01 (0.38 to 1.65)[a]	7846 (2127 to 13 565)[a]

Abbreviations: CCI, Charlson Comorbidity Index; LOS, length of stay; OR, odds ratio.

[a] $P < .05$.