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A comparison of open and minimally invasive surgery for hepatic and pancreatic resections using the nationwide inpatient sample

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Abstract

Background—The use of minimally invasive surgery (MIS) techniques for pancreatic and liver operations remains ill defined. We sought to compare inpatient outcomes among patients undergoing open versus MIS pancreas and liver operations using a nationally representative cohort.

Methods—We queried the Nationwide Inpatient Sample database for all major pancreatic and hepatic resections performed between 2000 and 2011. Appropriate International Classification of Diseases, 9th Revision (ICD-9) coding modifiers for laparoscopy and robotic assist were used to categorize procedures as MIS. Demographics, comorbidities, and inpatient outcomes were compared between the open and MIS groups.

Results—A total of 65,033 resections were identified (pancreas, $n = 36,195$ [55.7%]; liver, $n = 28,035$ [43.1%]; combined pancreas and liver, $n = 803$ [1.2%]). The overwhelming majority of operations were performed open ($n = 62,192$, 95.6%), whereas 4.4% ($n = 2,841$) were MIS. The overall use of MIS increased from 2.3% in 2000 to 7.5% in 2011. Compared with patients undergoing an open operation, MIS patients were older and had a greater incidence of multiple comorbid conditions. After operation, the incidence of complications for MIS (pancreas, 35.4%; liver, 29.5%) was lower than for open (pancreas, 41.6%; liver, 33%) procedures (all $P < .05$) resulting in a shorter median length of stay (8 vs 7 days; $P = .001$) as well as a lower in-hospital mortality (5.1% vs 2.8%; $P = .001$).

Conclusion—During the last decade, the number of MIS pancreatic and hepatic operations has increased, with nearly 1 in 13 HPB cases now being performed via an MIS approach. Despite MIS patients tending to have more preoperative medical comorbidities, postoperative morbidity, mortality, and duration of stay compared favorably with open surgery.

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During the last decade, minimally invasive surgery (MIS) has become used increasingly for a wide array of operative procedures. The MIS approach holds the promise of better cosmesis, fewer wound complications, a shorter hospital stay, and a quicker return to baseline functional status.^{1–6} Although all of these benefits have not been completely borne out in studies examining MIS versus open approaches for various surgical procedures,^{7,8} patients remain interested in the MIS approach.⁹ Laparoscopic cholecystectomy has been standard-of-care for nearly two decades, whereas the MIS approach for other complex abdominal operations has increased over time.¹⁰ The MIS approach has gained particular acceptance for colorectal,^{11–13} urologic,¹⁴ bariatric,¹⁵ and gynecological¹⁶ procedures. The MIS approach has also long been applied to certain aspects of hepatopancreaticobiliary (HPB) surgery such as distal pancreatectomy¹⁷ and minor hepatic resection.^{7,18} More recently, the MIS approach has gained increased acceptance for other more complicated HPB operative procedures such as pancreatoduodenectomy^{19,20} and major hepatic resections.^{21,22}

Previous studies have reported on the feasibility and safety of laparoscopic pancreatic and hepatic procedures.^{23–26} Recently, several centers have published data on the robotic approach to pancreatic and hepatic lesions.^{27–29} Most studies have noted that the MIS approach to pancreatic and hepatic surgery is safe, feasible, and can lead to comparable results as the open approach.^{30,31} Data on the MIS approach for HPB surgery remain, however, relatively scarce. In fact, most studies reporting on outcome comparing open versus the MIS approach for HPB surgery have been derived from the experience of single institutions.^{26,32,33} Data on the MIS approach for HPB surgery have been limited in that virtually all reports are derived from specialized, tertiary hepatobiliary centers.^{23–29} Previous studies that have included only academic medical centers may not reflect population-wide outcomes for HPB MIS surgery. Several previous studies have noted differences in HPB outcomes when comparing data from academic centers versus population-level data.^{34,35}

To better understand the relative use of MIS in HPB surgery, it is important and necessary to evaluate nationally representative data from the entire United States. Therefore, the objective of the current study was to define the overall use and temporal trends in the use of the MIS versus open approach for HPB surgery using data from the National Inpatient Sample (NIS) database. In addition, we examined the factors associated with receipt of MIS HPB surgery, as well as characterized in-hospital outcomes after MIS versus open HPB surgery.

METHODS

Data source

We queried the NIS database that is maintained by the Agency for Healthcare Research and Quality. The NIS database is the largest publicly available all-payer inpatient care database in the United States. The database contains discharge data from 1,045 hospitals in 46 states representing an approximate 20% sample of US hospitals.³⁶

Patient selection and data collection

All patients who underwent a major hepatic or pancreatic resection between 2000 and 2011 were identified using the appropriate *International Classification of Diseases*, 9th Revision (ICD-9) procedure codes: partial hepatectomy (50.22), hepatic lobectomy (50.3), pancreatectomy (52.0), partial pancreatectomy (52.5), proximal pancreatectomy (52.51), distal pancreatectomy (52.52), radical subtotal pancreatectomy (52.53), other partial pancreatectomy (52.59), total pancreatectomy (52.6), and radical pancreaticoduodenectomy (52.7). Appropriate ICD-9 coding modifiers for laparoscopy and robotic-assist were used to categorize procedures as MIS (laparoscopy: 54.21, robotic: 17.4, 17.41, 17.42, 17.43, 17.49). To minimize the number of patients in which the robotic modifier was unrelated to the liver or pancreas procedure, all patients who had additional procedure codes for urologic (602–606) or gynecologic (683–689) operations were excluded.

Standard patient characteristics were collected, including age, sex, and race. The primary payer, hospital teaching status, and hospital location were collected when available. Patient comorbidities and in-hospital perioperative complications (myocardial infarction, pneumonia, cerebrovascular accident, venous thromboembolism, acute renal failure, urinary tract infection, liver failure, wound complication and infection, ileus, fistula, shock, hemorrhage, and reoperation) were ascertained using the corresponding ICD-9 diagnostic codes.

Statistical analysis

Standard measures of frequencies and central tendency were calculated to summarize characteristics of patients, procedures, and in-hospital outcomes. Demographics, comorbidities, and multivariable-adjusted outcomes for complications and death were compared among patients undergoing open versus MIS procedures. We used multivariable logistic regression to adjust for variables, including sex, age, and comorbid conditions, that were significant on univariable analysis ($P < .05$). The χ^2 analysis was used for comparison of categorical variables and t test or Wilcoxon rank-sum test was used for continuous variables (significance level $< .05$). SAS version 9.3 (SAS Institute, Cary, NC) was used for all statistical analyses.

RESULTS

Patient and hospital characteristics

A total of 65,033 resections were identified (pancreas, $n = 36,195$, 55.7%; liver, $n = 28,035$, 43.1%; combined pancreas and liver, $n = 803$, 1.2%). There were slightly more females ($n = 33,159$, 51.2%) than males ($n = 31,604$, 48.8%) in the cohort (Table I). The median age was 60 years (interquartile range [IQR] 49–70) and the majority of patients were white ($n = 38,463$, 73.7%). Most cases were performed as an elective operation ($n = 44,465$; 77.4%), at a teaching hospital ($n = 45,883$; 80.7%), and in an urban setting ($n = 55,232$; 97.1%). Most operations were performed as an open procedure ($n = 62,192$; 95.6%), whereas the remaining 2,841 cases (4.4%) were MIS. The median length of stay (LOS) among all patients was 8 days (IQR 6, 14). The most common perioperative condition among patients

was hypertension ($n = 25,020$; 38.6%) followed by malignancy ($n = 15,690$; 24.2%) and diabetes ($n = 10,940$; 16.9%).

Case breakdown and operative approach

At the time of the operation, pancreas resection ($n = 36,195$; 55.7%) was performed more often than liver resection ($n = 28,035$; 43.1%; Table II). The most common pancreatic operation was a pancreaticoduodenectomy, accounting for 51.2% ($n = 17,613$) of all open pancreas cases and 53.2% ($n = 973$) of all MIS pancreas cases. Other common pancreatic procedures included distal pancreatectomy (open: 33.0% [$n = 11,371$] vs MIS: 35.3% [$n = 646$]). The most common surgery involving the liver was a partial hepatectomy, accounting for 66.8% ($n = 18,060$) of all open liver cases and 72.0% ($n = 711$) of all MIS liver cases; hepatic lobectomy was performed less often (open: 30.1% [$n = 8,341$] vs MIS: 23.2% [$n = 229$]).

The overwhelming majority of operations were performed open ($n = 62,192$, 95.7%), whereas 4.4% ($n = 2,841$) of hepato-pancreatic cases were MIS. Among MIS cases, most were laparoscopic ($n = 2,578$, 90.7%) whereas a small subset was performed with a robotic approach ($n = 263$, 9.3%). The overall number of MIS cases increased from 81 (2.3%) liver and pancreas cases in 2000 to 581 (7.5%) in 2011 (Fig 1). Among laparoscopic pancreatic operations, pancreaticoduodenectomy ($n = 919$, 56.1%) was most commonly performed, whereas a distal pancreatectomy was the most common robotic pancreatic resection ($n = 116$; 61.1%). Among liver cases, partial hepatectomy was the most common operation for both laparoscopic ($n = 656$; 71.7%) and robotic ($n = 55$; 75.3%) cases. Among MIS cases, robotic operations accounted for 10.4% of pancreas cases and 7.4% of liver cases. Robotic-assisted operations, first recorded in 2008 ($n = 9$; 0.1% of all cases), increased to 122 cases (1.6% of all cases) in 2011. Of note, by 2011 more than 1 in 5 (21.0%) of all MIS cases were performed via a robotic approach, with the majority of robotic cases (75%) being performed on the pancreas. Both the number of MIS pancreaticoduodenectomies (2000–2005: $n = 288$, 28.8% vs 2006–2011: $n = 711$, 71.2%) and major hepatectomies (2000–2005: $n = 71$, 29.5% vs 2006–2011: $n = 170$, 70.5%) increased over the time periods examined (both $P < .001$).

Factors associated with operative approach

When comparing cohorts, patients undergoing an MIS operation were often older (open: 60 years [IQR: 48, 70] vs MIS: 64 years [IQR: 54, 72]; $P = .0001$) and obese (body mass index >30) (open: $n = 2,997$, 4.8% vs MIS: $n = 184$, 6.6%) (both $P < .05$); in addition, patients undergoing an MIS approach were more likely to have comorbidities, including hypertension (open: $n = 23,760$, 38.3% vs MIS: $n = 1,260$, 45.5%; odds ratio [OR] 1.35, 95% 1.25–1.45; $P = .001$) and diabetes (open: $n = 10,390$, 16.7% vs MIS: $n = 550$, 19.8%; OR 1.23, 95% 1.12–1.14; $P = .001$) (Table I). Patients undergoing an MIS operation were also more likely to have Medicare coverage (open: 38.1% vs MIS: 44.3%; OR 1.69, 95% 1.42–2.00; $P = .001$). MIS operations were more commonly performed at a teaching hospital (open: 80.3% vs MIS: 87.7%; OR 1.74, 95% 1.53–1.98; $P = .001$) and in an urban setting (open: 97.1% vs MIS 98.8%; OR 2.50, 95% 1.69–3.70; $P = .001$). After adjustment on multivariate analyses, each of these factors remained independently associated with receipt of MIS surgery (Table III).

Open versus MIS outcomes

The incidence of complications was lower after an MIS procedure compared with an open procedure (OR 0.84, 95% 0.78–0.91; $P = .001$) (Fig 2). Specifically, on multivariate analysis, complications were less common with an MIS approach for pancreas (open: 41.6% vs MIS: 35.4%; OR 0.81, 95% 0.72–0.89; $P = .001$), yet were about the same for liver (open: 33.0% vs MIS: liver: 29.5%; OR 0.91, 95% 0.79–1.05; $P = .22$) procedures. The MIS associated decrease in complications was mostly related to fewer gastrointestinal (open: 15.6% vs MIS: 14.0%; OR 0.88, 95% 0.79–0.99; $P = .03$) and renal infectious (open: 6.1% vs MIS: 4.3%; OR 0.79, 95% 0.66–0.96; $P = .02$). Of note, infectious complications were comparable in both groups (open: 5.9% vs MIS: 5.2%; OR 0.85, 95% 0.71–1.02; $P = .09$) (Table IV). Reoperation was less common among patients undergoing an MIS pancreas (open: 3.8% vs MIS: 1.8%; OR 0.60, 95% 0.42–0.85; $P < .001$) and tended to be less for liver (open: 2.8% vs MIS: 1.4%; OR 0.59, 95% 0.33–1.05; $P = .07$) procedure. Compared with patients who underwent an open operation, patients who had an MIS approach had a slightly shorter median duration of stay (open: 8 vs MIS: 7 days; $P < .001$), as well as lower in-hospital mortality (open: 5.1% vs MIS: 2.8%; $P = .001$) (Fig 3). LOS and in-hospital mortality also was less among patients who underwent a “major” MIS HPB procedure (open vs MIS pancreaticoduodenectomy: median LOS, 10 (7, 17) vs 9 (6, 14) days ($P = .001$) and mortality 5.1% vs 2.9%; OR 0.64, 95% 0.47–0.86; $P = .004$; open vs MIS major hepatic resection: median LOS, 7 (5, 10) vs 6 (4, 8) days ($P = .001$) and mortality 5.4% vs 2.9%; OR 0.67, 95% 0.45–1.0; $P = .01$). On multivariate analysis after controlling for competing risk factors, all patients undergoing an MIS operation were more likely to have a lower incidence of in-hospital complications (OR 0.83, 95% confidence interval [95% CI] 0.74–0.90), reoperation (OR 0.55, 95% CI 0.41–0.73), and in-hospital mortality (OR 0.67, 95% CI 0.52–0.85), as well as a shorter LOS (OR 0.82, 95% CI 0.76–0.90) (all $P < .001$) (Table III).

DISCUSSION

In 1910, an internist from Stockholm named Han Christian Jacobaeus reported on the abdominal visualization of a small series of patients with ascites and coined the term “laparoscopy.”³⁷ During the past 100 years, there have been tremendous technological innovations and advancements in the field of MIS.³⁸ MIS is now used in virtually all realms of abdominal surgery. In fact, MIS is often the preferred operative approach for many gynecological procedures (eg, tubal ligation, etc),¹⁶ as well as general abdominal surgical procedures (eg, antireflux operations, bariatric surgery, etc).¹⁵ During the last decade, the MIS approach also has gained increasing acceptance and utilization for colorectal and thoracic procedures.^{11–13,39}

In addition, MIS has now expanded beyond pure laparoscopy to include robotic approaches. Although previous studies have documented the trends and outcomes of laparoscopic and robotic approaches for colorectal and thoracic surgical procedures,^{12,40,41} national data on HPB MIS has remained poorly defined. Most previous data on the topic of HPB MIS have come from highly specialized, tertiary centers of excellence.^{23–25,27–29} The current study is important because we defined the overall use and growth trend of HPB MIS in a nationally representative cohort. By using a dataset of nationally representative hospitals, we were

more able to characterize the general adoption of MIS techniques for HPB surgery across a broader cohort of institutions. Interestingly, we noted that the overall use of the MIS approach for HPB remained relatively low. In fact, during the 10-year time period examined, the overwhelming majority (95.7%) of operations were performed open, with only 4.4% of hepato-pancreatic cases being MIS. Perhaps not surprisingly, we did note an increased trend in the overall use of the MIS approach for HPB operations. Specifically, by 2011---the last year examined---the proportion of HPB MIS cases had increased to 7.5% compared with only 2.3% in 2000. Of note, although the incidence of complications, as well as LOS, for MIS was lower than for open procedures the differences were not dramatic.

Several reports have noted the expanded use of MIS in other subspecialty operations. For example, Bardakcioglu et al¹² reported a marked increase in the use of laparoscopic colectomy after 2004 with a particular inflection of more MIS colon cases after 2008. In several separate studies, the use of video-assisted thoracic surgery similarly has been shown to have increased in the late 2000s such that between 15 and 30% of all lobectomies in the United States are now performed using a MIS approach.^{42,43} In the current study, we noted a similar increase in the use of the MIS approach for HPB cases. Specifically, the overall number of MIS cases increased from 81 (2.3%) liver and pancreas cases in 2000 to 581 (7.5%) in 2011 (Fig 1). The proportion of all distal pancreatectomies performed via a MIS approach increased from 2.5% in 2000 to 11.8% in 2011; in comparison, although there were no MIS pancreaticoduodenectomy cases recorded in 2000, the proportion had increased to 8.8% by 2011. A similar trend was noted for minor and major hepatic resections (Fig 1).

It is interesting to note that, although there was an increase over time, overall use of the MIS approach for HPB surgery remained low at less than 10%. Interestingly, the use of robotic surgery in HPB was particularly low, with only 1.6% of all cases using this technology in 2011. The reason for the low use of MIS for liver and pancreas operations compared with other abdominal procedures is undoubtedly multifactorial. In part, the lower use of MIS is probably related to the fact that HPB cases tend to be technically complex, with steep learning curves for even open liver and pancreas resections.^{44,45} In addition, there is the further learning curve associated with techniques inherent to laparoscopic and robotic operations.^{46,47} Kluger et al⁴⁸ recently described the importance of development of proper skills in laparoscopic techniques to achieve acceptable perioperative outcomes. Although it is likely that the learning curve for these technically demanding operations is a major contributor to the current low use of MIS HPB surgery, as current trainees gain greater exposure to these techniques the adoption of MIS into complex abdominal operations will likely increase.⁴⁹

In the current study, we also noted that the majority of MIS operations were performed in teaching hospitals that were located in an urban setting. These findings are consistent with data suggesting that surgeons at nonteaching hospitals often perceive barriers to MIS procedures including limited access to operating room equipment, inadequate mentoring, as well as a lack of experience.⁵⁰ The finding that pancreaticoduodenectomy (MIS: 53.2%) was the most common pancreas MIS procedure may be related to the fact that most MIS surgery occurred in large, urban centers. Similar to the introduction of MIS approaches for other

surgical procedures,^{51,52} HPB MIS is likely to be centralized at large, teaching hospitals early in the adoption of these techniques.

In addition to hospital-level factors, several patient characteristics were found to be associated with receipt of HPB MIS. Unlike one previous report looking at the disparities in the use of MIS for colorectal disease,⁵³ Medicaid insurance status did not adversely impact the chance of a patient being offered an MIS approach for their HPB procedure. Patients of minority race were, however, less likely to undergo HPB MIS, suggesting a possible socioeconomic barrier to access. Interestingly, other patient specific factors such as age and perioperative comorbidities did not decrease a patient's chance of undergoing HPB MIS. In fact, patients undergoing MIS were older and had a greater incidence of several comorbidities, which may be related, in part, to more MIS procedures being performed at teaching hospitals. Recent advances in HPB surgery have improved perioperative morbidity and mortality.⁵⁴ As such, more patients with a greater comorbidity profile are being offered operative resection. Furthermore, as surgeons gain comfort and skills with MIS techniques over time, the restriction of these procedures to the "ideal" patient may be lessening as suggested by our data.

Regarding postoperative outcomes, we found that metrics such as overall complications, mortality, and LOS were roughly comparable after MIS versus open HPB surgery. Specifically, although complications were approximately 25% less common with an MIS approach for pancreas, morbidity was about the same for liver procedures. In addition, the risk of infectious complications was noted to be similar in both the MIS and open HPB groups. Nguyen et al²³ had similarly reported comparable morbidity among patients undergoing either open minor or major hepatic resections, whereas Pericleous et al⁵⁵ had noted the same among pancreatic surgery patients. LOS was shorter in the MIS group, with the difference being about 1 day on average. These data are consistent with previous prospective data based on patients undergoing colorectal surgery, which noted decreased hospital stay and improved quality of life with an MIS approach.⁵⁶ Taken together, the data strongly suggest that an MIS approach for HPB surgery can be associated with comparable morbidity and mortality, as well as a slightly decreased LOS for well selected patients.

There are a number of limitations that need to be considered when interpreting the data. Accuracy of coding for comorbid conditions is variable^{57,58} and often selected by the data entry personnel, favoring diagnoses with higher reimbursement rates.⁵⁹ The greater emphasis on coding complications for reimbursement purpose may explain, in part, the relatively stable incidence of perioperative complications recorded over time.⁶⁰ Any coding bias was, however, likely random with regard to the MIS versus open groups. As with all retrospective studies, the relative use of the MIS versus the open approach was undoubtedly affected by differential selection of patients who were felt to be better suited for a certain approach. Although we controlled for as many confounding factors as possible with multivariable logistic regression, we could not account for inherent selection bias, patient preference and anatomic differences.

In conclusion, the number of MIS pancreatic and hepatic operations has increased during the last decade with nearly 1 in 13 HPB cases now being performed via an MIS approach.

Despite MIS patients tending to have more preoperative medical comorbidities, postoperative morbidity and mortality, as well as LOS compared favorably with open surgery. As with other operative disciplines, HPB MIS will undoubtedly continue to expand over time. Further studies comparing MIS with open surgery will be needed to better elucidate proper patient selection, as well as characterize outcomes in a prospective setting.

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Fig 1.
Total number of operations over time stratified by operative approach.

Fig 2.
In-hospital complications over time stratified by operative approach.

Fig 3.
In-hospital mortality over time stratified by operative approach.

Table I

Patient and hospital characteristics by operative approach

	Open (<i>n</i> = 62,108)	MIS (<i>n</i> = 2,841)	<i>P</i> value
Age, yr (IQR)	60 (48,70)	64 (54,72)	.0001
Male sex	30,367 (48.8)	1,354 (48.8)	.99
Ethnicity			
White	36,720 (73.5)	1,743 (78.4)	
Black	4,949 (9.9)	169 (7.6)	.0001
Hispanic	4,497 (9.0)	156 (7.0)	
Other	1,745 (3.5)	53 (2.4)	
Comorbidities			
Hypertension	23,760 (38.3)	1,260 (45.5)	<.0001
Diabetes	10,390 (16.7)	550 (19.8)	<.0001
Chronic lung disease	3,909 (6.3)	224 (8.1)	.0002
Malignancy	14,885 (24.0)	805 (29.0)	<.0001
Obesity	2,997 (4.8)	184 (6.6)	<.0001
Chronic kidney disease	1,730 (2.8)	65 (2.3)	.17
Congestive heart failure	1,909 (3.1)	85 (3.1)	.99
Primary payer			
Medicare	23,604 (38.1)	1,228 (44.3)	
Medicaid	4,923 (7.9)	152 (5.5)	
Private/HMO Insurance	28,961 (46.7)	1,266 (45.7)	.0001
Self-pay	2,186 (3.5)	55 (2.0)	
Other	2,008 (3.2)	62 (2.2)	
Hospital location			
Urban	53,093 (97.1)	2,139 (98.8)	.0001
Rural	1,616 (3.0)	26 (1.2)	
Hospital teaching status			
Teaching	43,935 (80.3)	1,898 (87.7)	.0001
Nonteaching	10,774 (19.7)	267 (12.3)	

HMO, Health maintenance organization; *IQR*, interquartile range; *MIS*, minimally invasive surgery.

Table II

Procedure type stratified by operative approach

	Open (n = 62,192)	All MIS (n = 2,841)	Laparoscopic assisted (n = 2,578)	Robotic assisted (n = 263)	P value
Pancreas	34,367 (55.3)	1,828 (64.3)	1,638 (63.5)	190 (72.2)	.001
Partial pancreatectomy					.54
Proximal	538 (0.9)	27 (1.0)	25 (1.0)	2 (0.8)	.77
Distal	11,371 (18.3)	646 (22.7)	530 (20.6)	116 (44.1)	.05
Subtotal	337 (0.5)	18 (0.6)	15 (0.6)	3 (1.1)	.99
Other	2,467 (4.0)	105 (3.7)	94 (3.7)	11 (4.2)	.02
Total pancreatectomy	2,041 (3.3)	59 (2.1)	55 (2.0)	4 (1.5)	.001
Whipple	17,613 (28.3)	973 (34.2)	919 (35.6)	54 (20.5)	.10
Liver	27,047 (43.5)	988 (34.8)	915 (35.5)	74 (27.8)	.001
Lobectomy	8,341 (13.4)	229 (8.1)	215 (8.3)	14 (5.3)	.001
Partial hepatectomy	18,060 (29.0)	711 (25.0)	656 (25.4)	55 (20.9)	.001
Marsupialization	646 (1.0)	48 (1.7)	44 (1.8)	4 (1.5)	.001
Combined pancreas/liver	778 (1.2)	25 (0.9)	25 (1.0)	0	

All percentages (in parentheses) reflect proportion of cases within the given column (total open or MIS cases as indicated). MIS, Minimally invasive surgery.

Table III

Univariate and multivariate analysis of factors associated with MIS versus open approach

Variables	Univariate analysis			Adjusted analysis		
	OR	95% CI	P value	OR	95% CI	P value
Age >60 yrs	0.68	0.62–0.73	.001	0.75	0.69–0.82	.001
Female sex	0.99	1.07–0.91	.98	—	—	—
Race						
White	Ref	—	—	—	—	—
Black	0.72	0.61–0.84	<.001	0.79	0.67–0.94	.006
Hispanic	0.73	0.62–0.86	.002	0.80	0.67–0.95	.01
Chronic lung disease	1.31	1.14–1.51	.002	1.23	1.07–1.42	.004
Diabetes	1.23	1.12–1.14	.001	1.07	0.97–1.19	.15
Hypertension	1.35	1.25–1.45	.001	1.20	1.10–1.30	.001
Malignancy	1.30	1.19–1.41	.001	1.27	1.17–1.39	.001
Obesity	1.40	1.20–1.64	.001	1.18	1.01–1.39	.04
Teaching hospital	1.74	1.53–1.98	.001	1.71	1.49–1.97	.001
Urban hospital	2.50	1.69–3.70	.001	2.74	1.76–4.27	.001
Elective case	2.08	1.85–2.34	.001	1.97	1.75–2.22	.001
LOS >8 days	0.73	0.69–0.81	.001	0.82	0.76–0.90	.001
Reoperation	0.51	0.38–0.68	.001	0.55	0.41–0.73	.001
Death	—	—	—	0.67	0.52–0.85	.001
Complications	0.84	0.78–0.91	.001	0.83	0.74–0.90	.001

CI, Confidence interval; LOS, length of stay; MIS, minimally invasive surgery; OR, odds ratio.

Table IV

Perioperative outcomes by procedure type and operative approach

	All open	Open pancreas	Open liver	All MIS	MIS pancreas	MIS liver	P value
Any complications	23,411 (37.7)	13,887 (41.6)	9,209 (33.0)	927 (33.4)	634 (35.4)	281 (29.5)	.001
Myocardial infarction	2,188 (3.5)	1,349 (4.0)	818 (2.9)	105 (3.8)	66 (3.7)	39 (4.1)	.46
Pneumonia	1,393 (2.2)	872 (2.6)	495 (1.8)	44 (1.6)	36 (2.0)	8 (0.8)	.02
Cerebrovascular accident	413 (0.7)	218 (0.7)	185 (0.7)	22 (0.8)	17 (1.0)	5 (0.5)	.42
Thromboembolic event	1,795 (2.9)	1,121 (3.4)	643 (2.3)	75 (2.7)	57 (3.2)	18 (1.9)	.57
Acute renal failure	3,785 (6.1)	2,125 (6.4)	1,601 (5.7)	120 (4.3)	76 (4.2)	42 (4.4)	.001
Liver failure	1,116 (1.8)	280 (0.8)	817 (2.9)	35 (1.3)	12 (0.7)	21 (2.2)	.04
Urinary tract infection	4,148 (6.7)	2,574 (7.7)	1,513 (5.4)	154 (5.6)	106 (5.9)	48 (5.0)	.02
Wound complication	803 (1.3)	491 (1.5)	296 (1.1)	27 (1.0)	22 (1.2)	5 (0.5)	.14
Gastrointestinal complication	9,663 (15.6)	5,799 (17.4)	3,757 (13.4)	387 (14.0)	272 (15.2)	112 (11.7)	.02
Shock	435 (0.7)	271 (0.8)	156 (0.6)	21 (0.8)	15 (0.8)	5 (0.5)	.72
Infection	3,673 (5.9)	2,586 (7.7)	1,013 (3.6)	143 (5.2)	110 (6.1)	29 (3.0)	.098
Hemorrhage	2,807 (4.5)	1,659 (5.0)	1,115 (4.0)	112 (4.0)	71 (4.0)	37 (3.9)	.23
Reoperation	2,078 (3.3)	1,274 (3.8)	772 (2.8)	48 (1.7)	33 (1.8)	13 (1.4)	<.001
Other	2,651 (4.3)	1,535 (4.6)	1,079 (3.9)	109 (3.9)	69 (3.9)	39 (4.1)	.391
LOS >8 days	30,429 (49.0)	21,238 (63.6)	8,777 (31.4)	1,154 (41.6)	914 (51.1)	221 (23.2)	.001
Death	3,161 (5.1)	1,603 (4.8)	1,405 (5.0)	77 (2.8)	49 (2.7)	25 (2.6)	.001

LOS, Length of stay; MIS, minimally invasive surgery.