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Minimal-invasive approach to pancreatoduodenectomy is associated with lower early postoperative morbidity☆

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ABSTRACT

Objectives: We aim to investigate the impact of the operation time for pancreatoduodenectomy (PD) in different surgical approaches.
Methods: The NSQIP database was used to examine the clinical data of patients underwent PD during 2014–2016.
Results: We sampled a total of 6151 patients who underwent elective PD. Of these, 452(7.3%) had minimally invasive approaches to PD. Minimally invasive approaches (MIS) to PD was associated with a significant decrease in morbidity of patients (AOR: 0.67, $P < 0.01$). Following risk adjustment for morbidity predictors, operation length was statistically associated with post-operative morbidity (AOR: 1.002, $P < 0.01$). Although MIS procedures were significantly longer operations compared to open procedures (443 min vs. 371 min, CI: 53–82 min, $P < 0.01$), MIS approaches were associated with significantly decreased morbidity in low stage tumors (stage zero-II) (51.3% vs. 56.2%, AOR: 0.72, $P = 0.03$) and advanced stage disease (stage III-IV) (50% vs. 60.3%, AOR: 0.38, $P = 0.04$).
Conclusion: Minimally invasive approaches to PD were associated with decreased post-operative morbidity, even though they were associated with longer operative times. Operation length also significantly correlated with postoperative morbidity.

Introduction

Minimally invasive surgery (MIS) techniques have been developed to improve outcomes of surgical patients. The decrease in mortality, morbidity, and quicker return to daily activities using minimally invasive approaches has been reported for numerous procedures.[1–3] Utilization of minimally invasive techniques in the procedures with a high mortality and morbidity can be a practical way to decrease morbidity of patients. Pancreaticoduodenectomy (PD) in cancer surgery is a procedure which has a potential for curative therapy for some peri-ampullary malignancies. However, PD is associated with significant morbidity (25%–65%),[4–10] which can affect overall treatment plans for patients, especially in patients with multiple comorbid conditions. Utilization of minimally invasive techniques in PD might be a way to decrease morbidity of such patients. However, the complexity of PD makes MIS approaches more likely to be prolonged procedures. There are few comparative data available to support the routine use of minimally invasive approaches for complex operations such as pancreatic surgery.[11,12]

Even though minimally invasive approaches decrease morbidity of surgical patients, such approaches usually increase operative time and cost.[2,3] With the emergence of minimally invasive techniques in PD, it is important to understand the potential benefits and disadvantages of minimally invasive approaches. Recent studies reported no significant differences in overall cost of minimally invasive PD compared to open PD; thought due to increased postoperative cost for open PD,[12,13] but there was no data on operative length. However, there is limited data on the impact of operation time on postoperative complications for minimally invasive PD. This study aims to investigate the impact of the operation time of pancreatoduodenectomy in different surgical approaches on postoperative complications of patients.

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Methods

A retrospective study was conducted using the American College of Surgeons National Surgical Quality Improvement Program (ACS- NSQIP) database to investigate outcomes of patients who underwent PD during 2014–2016. We selected all patients underwent PD whose data were submitted to the ACS NSQIP during the study period of 1/1/2014 to 12/31/2016 using the Participant Use Data Files (PUF) and the target Pancreatectomy files. The NSQIP database is a comprehensive national surgical database that is directly extracted from the medical record by trained personnel.[14] The NSQIP database is collected in 650 participating hospitals of varying sizes and academic affiliations and includes 150 preoperative and intraoperative variables, in addition to 30 day postoperative morbidity and mortality.[14] Informed consents are obtained from individual patients within each hospital by the NSQIP and conducted studies from the database are exempt from IRB approval.[14]

We queried PD procedures based on the current procedural terminology (CPT) codes of 48150 (Pancreatectomy, proximal subtotal with total duodenectomy, partial gastrectomy, choledochoenterostomy and gastrojejunostomy with pancreatojejunostomy), 48152 (Pancreatectomy, proximal subtotal with total duodenectomy, partial gastrectomy, choledochoenterostomy and gastrojejunostomy without pancreatojejunostomy) for Whipple-type procedure; and 48153 (Pancreatectomy, proximal subtotal with near-total duodenectomy, choledochoenterostomy and duodenojejunostomy) and 48154 (Pancreatectomy, proximal subtotal with near-total duodenectomy, choledochoenterostomy and duodenojejunostomy) for pylorus sparing Whipple procedure. We included patients who had pancreatic cancer and underwent elective PD. We excluded patients who did not have information regarding the surgical approach and/or the stage of the pancreatic cancer.

Potential explanatory variables included demographics, comorbidities, perioperative laboratory data, hospitalization length, admission type, primary diagnosis, operative factors (operative length and surgical approach), and postoperative complications (such as sepsis, septic shock, overall morbidity, and mortality). The primary endpoints were morbidity of patients by surgical approach. Risk adjusted analysis was performed to compare morbidity of patients in different surgical approaches and investigate the effect of operation length on morbidity. All variables' definitions are accessible in the NSQIP website.[14]

Statistical analysis

All statistical tests were performed using the Statistical Package for Social Sciences (SPSS) software, Version 22 (SPSS Inc., Chicago, IL). Multivariate analysis using logistic regression was conducted to investigate associations between surgical approaches and postoperative complications. Univariate comparisons with a P value of less than 0.05 were then studied with multivariate analysis using logistic regression. The estimated adjusted odds ratio (AOR) with a 95% confidence interval were calculated for each correlation. The significance level was set at $p < 0.05$.

Results

We identified 6151 patients who underwent PD for pancreas cancer within the NSQIP database for 2014–2016. Overall, 1.3% of patients had stage zero cancer, 14.3% had stage one, 73.1% had stage II, 5% had stage III and 2.5% had stage IV cancer. The minimally invasive approach was used in 452 (7.3%), and 5699 (92.7%) patients had open resection. Patients who underwent minimally invasive approaches had a significantly higher mean operation time (mean difference: 443 min vs. 371 min, CI: 53–82 min, $P < 0.01$). The descriptive statistics, patient demographics, and clinical characteristics of the study populations are summarized in Table 1.

Risk adjusted analysis of 30 days postoperative complications, by surgical approach, is shown in Table 2. Overall morbidity of patients who underwent PD was 56.5%. Patients who underwent MIS surgery had less overall morbidity compared to open procedures (51.1 vs. 56.9%, AOR: 0.68, $P < 0.01$). Also, postoperative morbidity increased with increased operation length in all approaches (Fig. 2). Hospitalization length was one day shorter for minimally invasive PD compared to the open approach (10 days vs. 11 days, mean difference: 1 day, $P < 0.01$). However, there was no significant difference in mortality between planned open PD procedures and those approached minimally invasive (2.1% vs. 1.8%, AOR: 0.64, $P = 0.38$). Sub-analysis of data showed no significant difference in morbidity between MIS cases converted to an open procedure compared to planned open procedures (62.1% vs 56.9%, AOR: 1.30, $P = 0.42$).

The overall rate of MIS procedures was 7.3%. Utilization of MIS approaches for PD decreased from 13.2% in stage zero to 5.6% in stage III. Among patients who underwent MIS approaches to PD, 223 (49.3%) had laparoscopic or hand assisted laparoscopic PD surgery and 212 (46.9%) underwent robotic or hybrid PD surgery. Overall, the conversion rate of MIS approaches was 22.8% (31.4% for laparoscopic approach vs 15.6% for robotic approach, $P < 0.01$). Also, the conversion rate of MIS approaches to open increased from 10% in stage zero to 23% for stage II. When sub-analyzing the data for advance cancer patients (stage 3 and 4), MIS approaches had significantly lower morbidity (50% vs. 60.3%, AOR: 0.38, $P = 0.04$).

Minimally invasive approaches to PD had a significantly higher mean operation time compared to the open approach (mean difference: 443 min vs. 371 min, CI: 53–82 min, $P < 0.01$) (Fig. 1). Also, median operation time for successfully completed laparoscopic PD was 438 min compared to median operation time of successfully completed robotic PD of 433 min ($P = 0.93$). Patients who had a conversion to open surgery had the longest operation length (mean: 459 min) (Fig. 1).

On Multivariate analysis, several factors were associated with post-operative morbidity, with the strongest predictors being serum Creatinine more than 2.0 (AOR: 3.16, $P = 0.02$), serum albumin less than 3 mg/dL (AOR: 1.43, $P = 0.01$), pancreatic duct size less than 6 mm (AOR: 1.20, $P = 0.01$), and increased operative length (AOR: 1.002, $P < 0.01$); while MIS approach (vs open) was associated with less morbidity (AOR: 0.67, $P < 0.01$) (Table 3).

Discussion

This study found significant morbidity for patients who underwent PD (56.5%). This is in line with previous reports in literatures (25%–65%).[4–10] We reinforce the need for surgical innovation in order to reduce perioperative morbidity for these patients.[4] Our short-term results show benefits of utilization of minimally invasive approaches to PD. Our analysis shows that decreased rates of pneumonia, hemorrhagic complications needing transfusion, and overall morbidity were associated with a minimally invasive approach.

This study using multivariate analysis with adjustment of the result with multiple factors in an effort to decrease selection bias. However, two groups of patients who underwent MIS approaches and open surgery approach were not two homogeneous groups of patients. The MIS group had more patients with lower tumor stage, which may have influenced outcomes. Further studies are needed to compare MIS approaches with open PD between two homogeneous groups of patients.

Table 1
Demographics and clinical characteristics of patients underwent Pancreatoduodenectomy by surgical approach.

Variables		Surgical Approach		P-Value
		Minimal Invasive approach (N = 452)	Open approach (N = 5699)	
Age	Mean ± Standard Deviation (year)	64 ± 11	65 ± 11	0.32
	Median (year)	65	66	–
Sex	Female	204 (45.1%)	2632 (46.2%)	0.65
Race	White	381 (84.3%)	4445 (87.4%)	<0.01
	Black or African American	30 (6.6%)	388 (7.6%)	0.88
	Asian	23 (4%)	230 (4.5%)	0.95
	Other	12 (5.1%)	22 (0.4%)	0.85
Comorbidity	Hypertension	219 (48.5%)	3001 (52.7%)	0.08
	Diabetes Mellitus	99 (21.9%)	1463 (25.7%)	0.07
	Weight loss	49 (10.8%)	1007 (17.7%)	<0.01
	Chronic pulmonary disease	16 (3.5%)	231 (4.1%)	0.59
	Obesity	110 (24.3%)	1476 (26%)	0.44
	Congestive heart failure	0	25 (0.4%)	0.15
	Smoking	84(18.6%)	924 (16.2%)	0.19
	Ascites	2 (0.4%)	10 (0.2%)	0.21
	Chronic Steroid Use	11 (2.4%)	135 (2.4%)	0.93
Cancer Stage	Stage zero	10 (2.4%)	66 (1.2%)	0.05
	Stage I	87 (20.9%)	771 (13.9%)	<0.01
	Stage II	293 (70.3%)	3805 (73.5%)	0.04
	Stage III	17 (4.1%)	288 (5.1%)	0.21
	Stage IV	9 (2.2%)	132 (2.6%)	0.57
Pathology	Pancreatic Adenocarcinoma	311 (68.8%)	3947 (69.3%)	0.84
	Ampullary Carcinoma	43 (9.5%)	544 (9.5%)	0.98
	Distal Cholangiocarcinoma	13 (2.9%)	201 (3.5%)	0.46
	Duodenal Carcinoma	10 (2.2%)	179 (3.1%)	0.27
	IPMN-Invasive[a]	6 (1.3%)	124 (2.2%)	0.22
	Neuroendocrine Functioning	8 (1.8%)	74 (1.3%)	0.40
	Neuroendocrine Non-Functioning	39 (8.6%)	335 (5.9%)	0.01
	Other	22 (0.8%)	295 (5.2%)	0.77
Pancreas Reconstruction	Pancreaticojejunal duct-to-mucosal	394 (90%)	4926 (88.5%)	0.36
	Pancreaticojejunal invagination	36 (8.2%)	537(9.7%)	0.32
	Pancreaticogastreostomy	8 (1.8%)	101(1.8%)	0.98
Operation time	Mean ± Standard Deviation (Minutes)	443 ± 129	371 ± 130	<0.01
	Median (Minutes)	435	360	–
Type of Procedure	Whipple Classic	325 (71.9%)	3463 (60.8%)	<0.01
	Pylorus-sparing Whipple	127 (28.1%)	2236 (39.2%)	<0.01
Other Factors	Hard Pancreatic Gland Texture	139 (39.4%)	1999 (45.8%)	0.01
	Pancreatic Duct Size less than 6 mm	174 (48.2%)	2044 (45.3%)	0.29
	Preoperative Transfusion	2 (0.4%)	24 (0.4%)	0.94
	ASA[b]score more than two	359 (79.4%)	4356 (76.5%)	0.15
	Serum Creatinine >2 mg/dL	4 (0.9%)	36 (0.6%)	0.43
	Hypoalbuminemia[c]	25 (5.9%)	459 (8.6%)	0.05
	Vascular Reconstruction	30 (7.4%)	299 (6.2%)	0.45
	Pancreatic Drain	436 (96.7%)	4959 (87.1%)	<0.01
	Preoperative Obstructive Jaundice	209 (46.5%)	3010 (53.2%)	<0.01
	Preoperative Radiotherapy	31 (6.9%)	586 (10.3%)	0.01
	Preoperative chemotherapy	98 (21.7%)	1268 (22.3%)	0.76

[a] Intra-ductal Papillary Mucinous Neoplasms of the Pancreas.
[b] American Society of Anesthesiologists Score.
[c] Serum Albumin level less than 3 mg/dL.

We found that operation time was statistically associated with morbidity and mortality of patients after PD which is in line with previous published studies.[15–17] Although our data support associations between operation length and morbidity, the association could reflect anatomic difficulties and complexity of the operation, which could influence morbidity and mortality. In addition, the effect of operation length on morbidity of patients could be less than certain anatomic challenges such as need to vascular reconstruction or advance cancer staging. Even in advanced cancer patients (who had prolonged MIS operation times), the benefits of MIS approaches to decreased morbidity were still significant. The improvement in minimally invasive skills of pancreatic surgeons as a practical way to decrease operation time needs further consideration. However, prolonged operation time, alone, should not be considered when choosing between an open PD vs. MIS approach. And, we recognize that multiple factors can influence operation time including: case complexity, obesity, advanced tumor stage, and anatomic conditions. These factors could also influence morbidity independent of operative length. But, these considerations cannot be fully answered with the NSQIP database. In addition, even in MIS procedures converted to open, which had the longest operation time, post-operative morbidity was not worse than planned open procedures.

The two groups were similar, but, patients who had MIS surgery had less preoperative weight loss and jaundice before operation; and cases with a MIS approach had significantly more stage 0 and stage I tumors. Since low albumin also correlated with post-operative morbidity, this needs to be considered when analyzing this data. This reflects trends to use open surgery for patients with more advanced disease or comorbid conditions. However, patients with more comorbid conditions might also benefit from MIS approaches. In sub-analysis of the data for patients with stage 3 and 4 cancer we found a significant decrease in morbidity of patients who underwent MIS surgery compared to open. The concept of avoiding

Table 2
Risk adjusted analysis of postoperative complications of patients who underwent Pancreatoduodenectomy by surgical approach.

Outcomes	Surgical Approach		Adjusted Odd Ratio	95% Confidence Interval	P Value
	Minimal Invasive approach (N = 452)	Open approach (N = 5699)			
30 days Mortality	8(1.8%)	117(2.1%)	0.62	0.21–1.81	0.38
30 days Overall Morbidity	231(51.1%)	3245(56.9%)	0.67	0.51–0.87	<0.01
Severe postoperative morbidity[a]	163(36.1%)	2465(43.3%)	0.58	0.44–0.77	<0.01
Superficial Surgical Site Infection	31(6.9%)	505(8.9%)	1.05	0.66–1.68	0.81
Deep Surgical Site Infection	5(1.1%)	93(1.6%)	1.02	0.38–2.69	0.96
Organ Space Surgical Site Infection	52(11.5%)	798(14%)	0.66	0.44–1.01	0.05
Wound Disruption	5(1.1%)	70(1.2%)	0.55	0.12–2.41	0.43
Sepsis	22(4.9%)	515(9%)	0.62	0.36–1.03	0.06
Septic Shock	13(2.9%)	146(2.6%)	1.23	0.52–2.91	0.63
Delay Gastric Empty	79(17.6%)	909(16.2%)	1.17	0.84–1.63	0.35
Ventilator Dependency more than 48 h	10(2.2%)	132(2.3%)	0.86	0.32–2.28	0.76
Cardiac Arrest needs Cardiopulmonary Resuscitation	4(0.9%)	54(0.9%)	0.79	0.316–3.81	0.77
Acute renal Failure	2(0.4%)	38(0.7%)	0.31	0.03–2.69	0.29
Progressive Renal Failure	2(0.4%)	33(0.6%)	0.37	0.04–3.47	0.38
Hemorrhagic Complication needs transfusion	55(12.2%)	1110(19.5%)	0.50	0.33–0.76	<0.01
Deep Vein Thrombosis	11(2.4%)	157(2.8%)	1.26	0.54–2.92	0.58
Pulmonary Embolism	8(1.8%)	59(1%)	1.83	0.58–5.79	0.30
Urinary Tract Infection	19(4.2%)	177(3.1%)	1.18	0.56–2.46	0.65
Myocardial Infarction	2(0.4%)	61(1.1%)	0.38	0.05–2.95	0.35
Pneumonia	6(1.3%)	207(3.6%)	0.12	0.01–0.90	0.03
Unplanned Intubation	14(3.1%)	186(3.3%)	1.19	0.57–2.48	0.63
Central vascular Accident	1(0.2%)	13(0.2%)	1.03	0.12–8.58	0.97
Reoperation	29(6.4%)	267(4.7%)	1.13	0.63–2	0.67
Unplanned Readmission	83(18.4%)	894(15.7%)	0.87	0.61–1.25	0.46
Prolonged Hospitalization[b]	16(3.5%)	153(2.7%)	1.16	9.51–2.65	0.71
Pancreatic Fistula Overall	83(18.5%)	956(16.9%)	0.85	0.59–1.22	0.38
Pancreatic Fistula Needs Reoperation	5(6%)	49(5.1%)	1.01	0.19–5.23	0.99
Pancreatic Fistula treated with Drainage	25(30.1%)	278(29.1%)	1.47	0.71–3.07	0.29

[a] Includes: Organ Space Surgical Site Infection, Sepsis, Septic Shock, Ventilator Dependency, Cardiac Arrest, Acute renal Failure, Hemorrhagic Complication needs transfusion, Pulmonary Embolism, Myocardial Infarction, Pneumonia, Central vascular Accident, Reoperation, and Pancreatic Fistula.
[b] Hospitalization longer than 30 days.

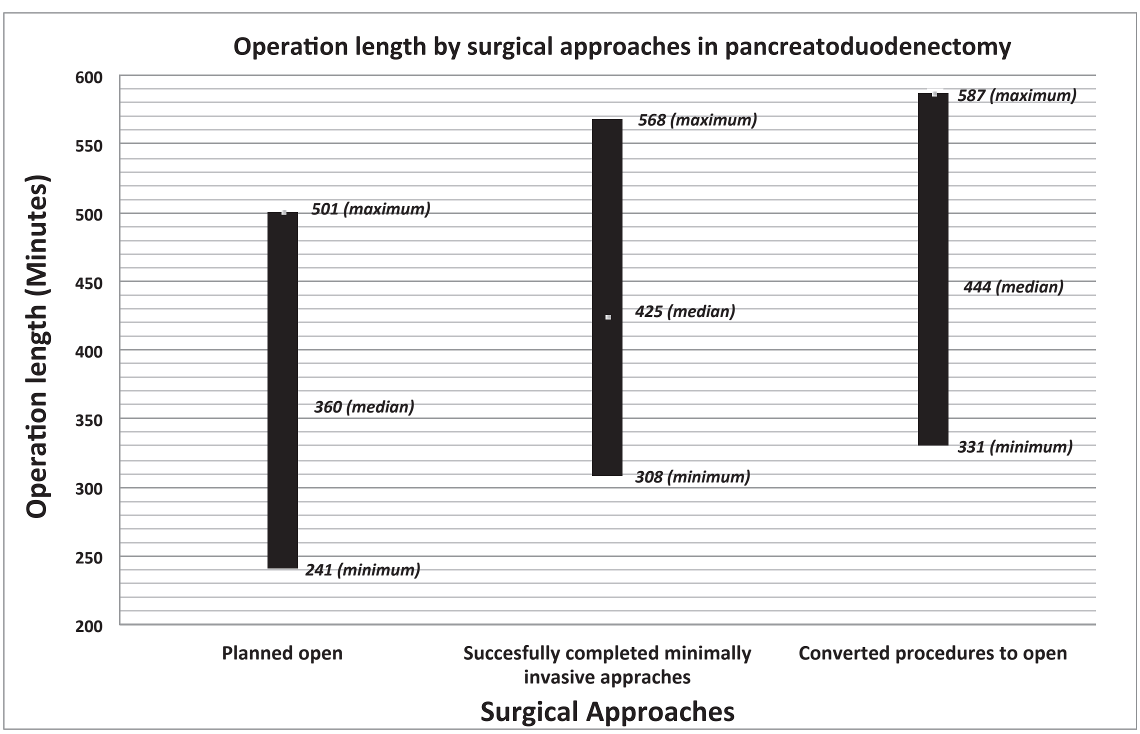

Fig. 1. Operation length by surgical approaches in pancreatoduodenectomy.

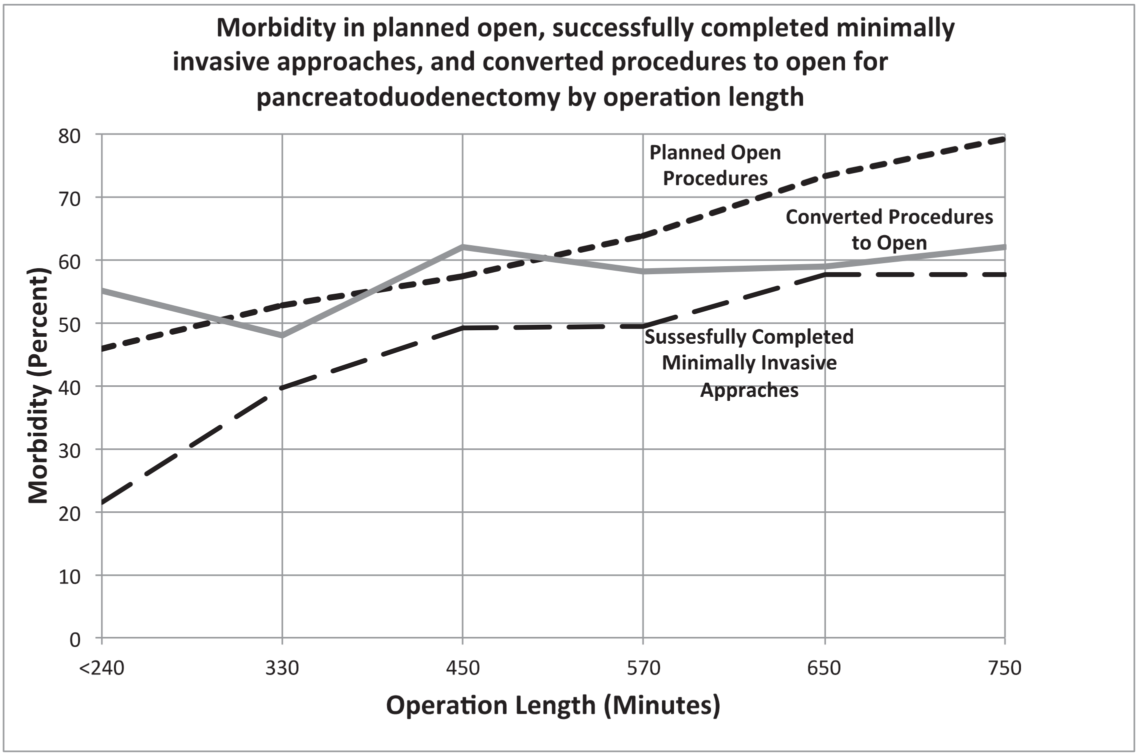

Fig. 2. Morbidity in planned open, successfully completed minimally invasive approaches and converted procedures to open for pancreatoduodenectomy by operation length.

MIS surgery for advanced cancer patients needs to be reevaluated. However, long-term follow-up of such patients regarding tumor recurrence is also needed.

National MIS training for pancreases surgeons is needed. We found the adoption rate of 7.3% for minimally invasive approaches to PD which is lower than other procedures.[1,18,19] The rate speaks to the need for a nationwide training program to prepare pancreas surgeons to perform more minimally invasive operations. However, minimally invasive approaches to PD are highly complex operations with a steep learning curve and are not widely adopted in the US and are limited to tertiary referral centers.[4,20,21] Previous studies reported that the surgical times for minimally invasive and open approaches to PD are comparable after an initial learning curve, even when the surgery involved major venous resection.[22–24] Further efforts are needed to improve pancreatic surgeons' abilities in minimally invasive PD, providing opportunities for learning, reviewing, and exploring possible advantages of a MIS approach. The current data suggest that prolongation of operative times should not prohibit MIS approaches in pancreas surgery.

Our study results show a conversion rate of 22.8% for minimally invasive PD. Zeh et al. reported a conversion rate of 16% for minimally invasive PD.[25] As expected, the conversion rate of minimally invasive approaches to PD is higher than other abdominal procedures which is likely related to the complexity of minimally invasive PD[1,18,19]. When comparing the conversion rate of the laparoscopic approach to PD with the robotic approach we found a significantly lower conversion rate in the robotic approach (31.4% vs. 15.6%, $P < 0.01$). Features of robotic surgery such as high-quality and three-dimensional vision, restoration of the eye-hand-target axis, better depth perception, tremor elimination, and more precise dissection have been reported as advantages of the robotic approach.[26,27] After developing experience, the conversion rate might decrease even more. But, longer operation length with the robotic approach, compared to the laparoscopic approach, has been reported, which needs to be considered in light of our results.[26,28] Interestingly, in the current study, we found the operative length or the laparoscopic approach and robotic approach to be similar (438 vs. 433 min), and not statistically different ($P = 0.93$).

Our study results show pancreatic fistula with the rate of 17% is one of the most common complications of the PD procedure, which is in line with previously published articles.[4,29] The complexity of the pancreatic anastomosis has been cited as one of the obstacles to widespread adoption of minimally invasive techniques for PD[4]. However, there was no significant difference in pancreatic fistula risk between minimally invasive and open technique. These results agree with studies by Previously Buchs, Chalikonda, and Asbun who reported no significant differences in pancreatic fistula rates between minimally invasive and open techniques.[11,12,30]

We found minimally invasive approaches to PD were associated with decreased rates of hemorrhagic complications needing blood transfusion. This is in line with previously published studies on benefits of minimally invasive approaches in decreasing hemorrhagic complications.[11,31] The relationship between operative blood loss and survival rate following PD has also been described.[32]

Study limitations

There are some limitations to the current study. This study is limited by its retrospective nature and we are unable to draw causal conclusions and the reported associations need to be confirmed by clinical trials. Also, we were unable to control for all unknown variables on multivariable models, which can introduce bias. While a significant number of variables are collected by NSQIP, some important variables were not captured such as total hospital charges, the reason of conversion of minimally invasive approaches to open, biliary leakage complication and treatment, and amount of blood transfusion intraoperatively. Although we reported benefits of minimally invasive approaches to PD within 30 days of discharge,

Table 3
Risk adjusted analysis of factors associated with morbidity of patients who underwent Pancreatoduodenectomy.

Factors		Adjusted Odd Ratio	95% Confidence Interval	P Value
Age	Age >70 years	0.86	0.23–3.13	0.82
Sex	Sex (female vs. male)	0.87	0.76–1.01	<0.06
Comorbidity	Weight loss	0.90	0.75–1.09	0.30
	Chronic pulmonary disease	1.40	0.95–2.06	0.08
	Obesity	1.21	1.02–1.42	0.02
	Congestive heart failure	2.66	0.48–14.54	0.25
	Smoking	1.02	0.84–1.24	0.79
	Ascites	0.60	0.09–3.77	0.59
	Hypoalbuminemia[b]	1.43	1.09–1.89	0.01
	Chronic Steroid Use	1.47	0.92–2.35	0.10
	Hypertension	1.34	1.16–1.56	<0.01
	Diabetes Mellitus	0.91	0.77–1.08	0.30
Type of the procedure	Pyloric sparing Whipple	–	–	–
	Classic Whipple	1.02	0.89–1.18	0.71
Surgical Approach	Open	–	–	–
	Minimally invasive approach	0.67	0.51–0.87	<0.01
Cancer Stage	Stage 0	–	–	–
	Stage 1	1.11	0.55–2.26	0.75
	Stage 2	1.26	0.66–2.39	0.47
	Stage 3	0.93	0.29–3.01	0.91
	Stage 4	1.36	0.31–5.91	0.68
Reconstruction type	Pancreaticojejunal duct-to-mucosal	–	–	–
	Pancreaticojejunal invagination	0.88	0.68–1.12	0.31
	Pancreaticogastreostomy	0.87	0.48–1.59	0.66
Pathology	Pancreatic adenocarcinoma	–	–	–
	Ampullary carcinoma	1.37	1.07–1.74	0.01
	Distal cholangiocarcinoma	1.28	0.86–1.90	0.21
	Duodenal carcinoma	1.49	0.96–2.32	0.07
	IPMN- invasive[c]	0.51	0.30–0.86	0.01
	Neuroendocrine-Functioning	1.38	0.67–2.80	0.37
	Neuroendocrine-non Functioning	1.16	0.83–1.62	0.36
	Others	1.30	0.92–1.84	0.13
Other factors	Operation length	1.002	1.002–1.003	<0.01
	Serum Creatinine level higher than 2	3.16	1.14–8.73	0.02
	Need for vascular reconstruction	0.92	0.64–1.30	0.65
	Pancreatic duct size less than 6 mm	1.20	1.04–1.39	<0.01
	Preoperative chemotherapy	0.90	0.73–1.12	0.37
	Preoperative radiotherapy	1.15	0.85–1.55	0.35
	Presence of a drain	1.05	0.85–1.29	0.63
	Preoperative Jaundice	1.04	0.89–1.22	0.59
	Pancreas hard texture	0.63	0.54–0.73	<0.01
	Preoperative need for transfusion	1.06	0.20–5.45	0.94
	ASA score more than two[a]	1.27	1.07–1.50	<0.01

[a] American Society of Anesthesiologists Score.
[b] Serum Albumin level less than 3 mg/dL.
[c] Intra-ductal Papillary Mucinous Neoplasms of the Pancreas.

we did not have any information regarding long-term outcomes such as local recurrence of malignancy. Although we used multiple exclusion criteria and we adjusted study results with multiple factors such as cancer stage to decrease selection bias, two groups of patients who underwent MIS approaches and the open surgery approach were not two homogeneous groups of patients. We found shorter hospitalization length for minimally invasive PD compared to the open approach (but only by one day). However, due to limitations of the study we could not evaluate if using minimally invasive approaches could decrease total hospital charges of the patients. This is important, since hospitalization times were very similar, and increased operative length is likely to increase costs. This study compared minimally invasive approaches to PD with open PD. However, patients who underwent open PD might have anatomic or medical conditions making minimally invasive approaches difficult or even impossible. Despite these limitations, this study is one of the few studies to report the impact of operation time in different approaches to PD.

Conclusion

Overall, minimally invasive approaches to PD were used in 7.3% of patients in our study. Minimally invasive approaches to PD were associated with less postoperative pneumonia, hemorrhagic complication, and overall morbidity compared to the open approach. Although our data support associations between operation length and morbidity of patient, exact reasons for this increased operative time are not available in the database; anatomic difficulties and complexities of the operation could be a factor, which might also influence post-operative morbidity.

Disclosures

There is nothing to disclose.

Source of founding

There is nothing to disclose.

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Dr. Moghadamyeghaneh had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.amjsurg.2018.04.009.

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