J Gastrointest Surg (2017) 21:1784–1792
DOI 10.1007/s11605-017-3543-6

ORIGINAL ARTICLE

Robotic Versus Laparoscopic Pancreaticoduodenectomy: a NSQIP Analysis

Ibrahim Nassour[1] · **Sam C. Wang**[1,2] · **Matthew R. Porembka**[1,2] · **Adam C. Yopp**[1,2] · **Michael A. Choti**[1,2] · **Mathew M. Augustine**[1,2] · **Patricio M. Polanco**[1,2] · **John C. Mansour**[1,2] · **Rebecca M. Minter**[1,2,3]

Received: 10 June 2017 / Accepted: 7 August 2017 / Published online: 17 August 2017

Abstract

Background An increasing body of literature is supporting the safety of minimally invasive pancreaticoduodenectomy compared to open pancreaticoduodenectomy, but there are limited comparative studies between laparoscopic and robotic pancreaticoduodenectomy.

The aim of this study was to compare the rate of postoperative 30-day overall complications between laparoscopic and robotic pancreaticoduodenectomy.

Methods Patients who underwent laparoscopic and robotic pancreaticoduodenectomy were abstracted from the 2014–2015 pancreas-targeted American College of Surgeons National Surgical Quality Improvement Program. A multivariable logistic regression model was developed to determine if the type of minimally invasive approach was associated with 30-day overall complications.

Results We identified 428 minimally invasive pancreaticoduodenectomy cases, of which 235 (55%) were performed laparoscopically and 193 (45%) robotically. Patients who underwent the robotic approach were more likely to be white compared to those who underwent the laparoscopic approach and were less likely to have pulmonary disease, undergo preoperative radiotherapy, and have vascular and multivisceral resection. On multivariable analysis, we found that the type of minimally invasive approach, whether laparoscopic or robotic, was not associated with overall complications. The predictors of 30-day overall complications were higher body mass index (odds ratio [OR], 1.05; 95% confidence interval [CI], 1.02–1.09), vascular resection (OR, 2.10; 95% CI, 1.23–3.58), and longer operative time (OR, 1.002; 95% CI, 1.001–1.004).

Conclusions Robotic pancreaticoduodenectomy was associated with a similar 30-day overall complication rate to laparoscopic pancreaticoduodenectomy. Further studies are needed to corroborate these findings and to establish the best approach to perform this complex operation.

Keywords Minimally invasive · Laparoscopic · Robotic · Pancreaticoduodenectomy · NSQIP

Electronic supplementary material The online version of this article (doi:10.1007/s11605-017-3543-6) contains supplementary material, which is available to authorized users.

✉ Rebecca M. Minter
Rebecca.Minter@UTSouthwestern.edu

1 Division of Surgical Oncology, Department of Surgery, University of Texas Southwestern Medical Center, Dallas, TX 75390, USA

2 University of Texas Southwestern Medical Center, Simmons Comprehensive Cancer Center, Dallas, TX 75390, USA

3 Division of Surgical Oncology, UT Southwestern Medical Center, 5323 Harry Hines Blvd, Dallas, TX 75390-9031, USA

Introduction

The adoption of minimally invasive pancreaticoduodenectomy (MIPD) has been cautious due to the complexity of the operation, the need to perform multiple delicate anastomoses, the concern for suboptimal oncological outcomes, and the high morbidity of the operation, even when performed in an open approach.[1] Recently, multiple studies have suggested that MIPD is safe and feasible, especially in high-volume centers, with inferior outcomes in low-volume hospitals.[2–14] Most of these studies were either a case series of laparoscopic or robotic operations or observational comparative studies between MIPD and open pancreaticoduodenectomy (OPD).[2–14] The majority of these reports showed that MIPD has at least equivalent postoperative and oncological outcomes compared to OPD, but few studies have compared laparoscopic (LPD) versus robotic pancreaticoduodenectomy (RPD) to determine which minimally invasive platform may be best to adopt more broadly.[14–19]

Currently the surgery field is divided between centers supporting LPD or RPD without objective evidence of the superiority of one approach over the other. The advocates of LPD propose that laparoscopy is already engrained in surgical training and thus its adoption to another operation such as pancreaticoduoedenectomy (PD) should be easier than adopting the robotic platform, which is not usually used by residents or even fellows.[6] The proponents of RPD suggest that the improved visual perception and ergonomics of the robotic platform allow for easier dissemination of this platform and possibly better outcomes, yet there are no large comparative studies evaluating the impact of the minimally invasive platform utilized on postoperative outcomes.[20]

The primary aim of this study was to compare RPD and LPD with respect to 30-day overall complication rates using the pancreas-targeted American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database.

Materials and Methods

Study Design

We used the 2014–2015 pancreas-targeted ACS-NSQIP database to perform a retrospective study comparing robotic and laparoscopic cases. The NSQIP program collects more than 150 variables from 500 participating hospitals, including preoperative, intraoperative, and 30-day postoperative mortality and morbidity outcomes.[21] The pancreas-targeted component has an additional 26 variables specific to pancreatectomy in comparison to the general NSQIP database and is only available at 120 hospitals. The ACS-NSQIP database is maintained by trained and certified surgical clinical reviewers who collect and enter the data, and the web-based database is audited periodically to ensure the highest quality.[21]

Patient Selection

After merging the pancreas-targeted NSQIP participant user data files with the general database, we selected the following current procedural terminology (CPT) codes: 48150, 48152 (classic Whipple-type procedure with and without pancreatojejunostomy), 48153, and 48154 (pylorus-preserving PD [PPPD] with and without pancreatojejunostomy). The following patients were excluded (Fig. 1):

Patients who

1. Underwent a nonelective procedure;
2. Underwent a hybrid procedure. The NSQIP defines a hybrid procedure as "a combination of approaches not otherwise specified," making it unclear how these operations were performed;
3. Had missing data.

The diagnosis group was divided into pancreatitis, T_0–T_2 malignant, T_3–T_4 malignant, ≤ 5 cm benign, and > 5 cm benign lesions. We defined multivisceral resection as a colonic, hepatic, and/or intestinal resection performed with MIPD. MIPD was defined as LPD or RPD.

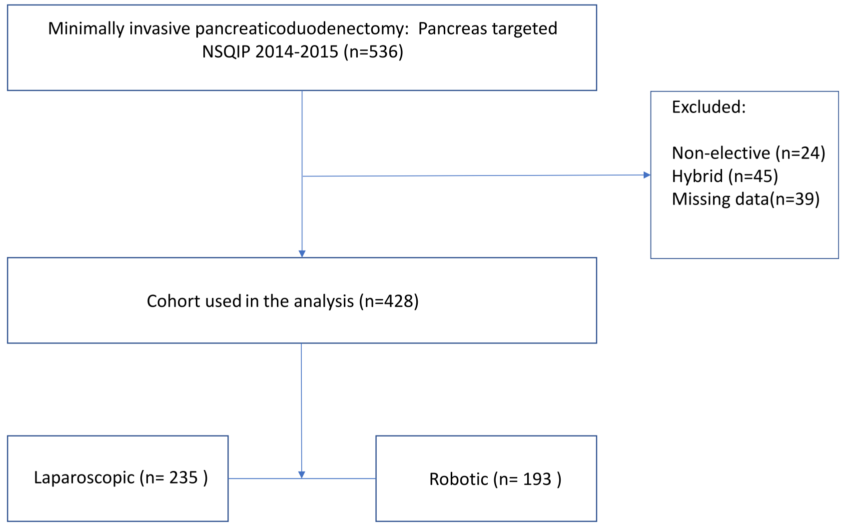
Outcomes

The primary outcome of this study was the 30-day overall complication rate, and the secondary outcome was the conversion rate. A patient who had any of the following was considered to have a major complication: pneumonia, unplanned intubation, pulmonary embolism, on ventilator for > 48 h, deep surgical site infection, organ space surgical site infection, dehiscence, bleeding requiring transfusion within the first 72 h of surgery start time, deep vein thrombosis/thrombophlebitis, cerebrovascular accident, cardiac arrest, myocardial infarction, sepsis/septic shock, renal failure, or postoperative pancreatic fistula.

Statistical Analysis

We used SPSS version 24 to perform all statistical analysis. Categorical variables were presented as counts and proportions, and continuous variables were presented as means with standard deviations or medians. We performed a t test or univariate logistic regression for continuous variables and a chi-squared or Fischer's exact or univariate logistic regression test, when appropriate, for categorical variables. To determine the association of the type of minimally invasive technique with overall complications, we adjusted for pre- and intraoperative factors using forward multivariable logistic regression. As a secondary analysis, we determined the predictors of conversion by using a forward multivariable logistic regression. Variables with $p < 0.25$ on univariate analysis were explored in both models, and only statistically significant variables were kept in the final models. Two-tailed tests were used with the significance level set at < 0.05.

Fig. 1 CONSORT diagram



Results

Baseline Characteristics of RPD and LPD

We identified 428 MIPD cases, of which 235 (55%) were performed laparoscopically and 193 (45%) were performed robotically (Fig. 1). Patients who underwent RPD were more likely to be white compared to those who underwent LPD (88.6 vs 78.7%; $p = 0.024$), less likely to have dyspnea (2.1 vs 6.0%; $p = 0.046$), and less likely to undergo preoperative radiotherapy (2.6 vs 9.4%; $p = 0.004$). In addition, RPD patients were less likely to undergo vascular resection (12.4 vs 23.4%; $p = 0.004$) and multivisceral resection (4.7 vs 12.3%; $p = 0.005$) but were more likely to have drains placed (99.0 vs 92.8%; $p = 0.002$). All other baseline characteristics were similar (Table 1).

Perioperative Outcomes of RPD and LPD

An unadjusted comparison showed that RPD was associated with a lower conversion rate compared to LPD (11.4 vs 26.0%; $p = 0.004$; Table 2). There was no difference in operative time, reoperation rate, length of stay, 30-day mortality, and overall and major complication rates. RPD was associated with increased superficial surgical site infections (9.3 vs 3.8%; $p = 0.020$), but there was no difference in all other complications, including postoperative pancreatic fistula and delayed gastric emptying.

On multivariable analysis, we found that the type of minimally invasive approach, whether laparoscopic or robotic, was not associated with overall complications (Table 3). The predictors of overall complication were higher body mass index (odds ratio [OR], 1.05; 95% confidence interval [CI], 1.02–1.09), vascular resection (OR, 2.10; 95% CI, 1.23–3.58), and operative time (OR, 1.002; 95% CI, 1.001–1.004).

Conversion of MIPD: Predictors

The overall conversion rate for MIPD was 19.4% (Table 4). The independent predictors of conversion were dyspnea (OR, 4.56; 95% CI, 1.63–12.74), PPPD (OR, 2.42; 95% CI, 1.33–4.39), multivisceral resection (OR, 2.86; 95% CI, 1.32–6.23), and vascular resection (OR, 5.30; 95% CI, 2.97–9.45). After adjusting for these factors, robotic surgery was independently associated with a lower odds of conversion (OR, 0.46; 95% CI, 0.26–0.81).

Discussion

In this large study from a national cohort of patients, we found that robotic surgery was associated with a similar 30-day overall complication rate in an intention-to-treat comparison to LPD. Furthermore, we found that RPD was associated with a lower conversion rate. The predictors of conversion were dyspnea, PPPD, laparoscopic approach, and multivisceral and vascular resection. This report provides evidence that both approaches seem to have similar 30-day outcomes, with RPD having the advantage of a lower conversion rate.

Robotic surgery is thought to be superior to laparoscopy in different disciplines, including urological,[22] gynecological,[23] colorectal,[24] gastric,[25] and distal pancreatic operations,[26] but none have compared RPD to LPD in a large study,[19] as few institutions perform this complex operation using minimally invasive techniques, and the majority have adopted one approach versus the other, preventing single institutional comparison. The robotic platform provides a magnified three-dimensional image, 7 degrees of freedom, and eliminates hand tremor and the fulcrum effect of rigid laparoscopic instruments—allowing for precise suturing, easier tissue handling, better control of large blood vessels, and the ability to work at angles not possible with the laparoscope. Such advantages are

Table 1 Patient, tumor, and operative characteristics

	Laparoscopic PD, *n* (%)	Robotic PD, *n* (%)	*p* value
Total patients	235 (54.9)	193 (45.1)	
Gender			
Female	106 (45.1)	92 (47.7)	0.597
Male	129 (54.9)	101 (52.3)	
Age (mean, SD; years)	63.4 (11.6)	63.5 (11.9)	0.962
Race			0.024
White	185 (78.7)	171 (88.6)	
African American	25 (10.6)	12 (6.2)	
Others/unknown	25 (10.6)	10 (5.2)	
Body mass index (mean, SD; kg/m^2)	27.6 (6.6)	27.8 (5.3)	0.682
Obstructive jaundice			0.306
No	143 (60.9)	108 (56.0)	
Yes	92 (39.1)	85 (44.0)	
Weight loss			0.376
≤ 10% loss	211 (89.8)	168 (87.0)	
> 10% loss	24 (10.2)	25 (13.0)	
ASA class			0.162
Class I	1 (0.4)	3 (1.6)	
Class II	56 (23.8)	42 (21.8)	
Class III	172 (73.2)	136 (70.5)	
Class IV	6 (2.6)	12 (6.2)	
Diabetes mellitus	54 (32.0)	47 (24.4)	0.739
Hypertension	113 (48.1)	103 (53.4)	0.277
Dyspnea	14 (6.0)	4 (2.1)	0.046
Diagnosis group			0.912
≤ 5 cm, benign	29 (12.3)	28 (14.5)	
> 5 cm, benign	7 (3.0)	4 (2.1)	
T0–T2, malignant	50 (21.3)	44 (22.8)	
T3–T4, malignant	138 (58.7)	109 (56.5)	
Pancreatitis	11 (4.7)	8 (4.1)	
Neoadjuvant chemotherapy	38 (16.2)	42 (21.8)	0.140
Neoadjuvant radiotherapy	22 (9.4)	5 (2.6)	0.004
Surgery type			
Whipple	181 (77.0)	144 (74.6)	0.562
PPPD	54 (23.0)	49 (25.4)	
Vascular resection	55 (23.4)	24 (12.4)	0.004
Multivisceral resection	29 (12.3)	9 (4.7)	0.005
Intraoperative drains	218 (92.8)	191 (99.0)	0.002

ASA American Society of Anesthesiologists, *PD* pancreaticoduodenectomy, *PPPD* pylorus-preserving pancreaticoduodenectomy, *SD* standard deviation

important, especially in a complex operation such as PD due to the need to perform intracorporal anastomoses such as the pancreatojejunostomy and hepaticojejunostomy. In this report, we have shown that there was no difference between the approaches in adjusted overall complications; however, we could not determine the severity of complications as described by the Clavien-Dindo classification as the NSQIP database lacks this variable. The robotic platform was superior to laparoscopy with respect to conversion, even after adjusting for important factors associated with conversion like concomitant vascular and multivisceral resection.

Identifying risk factors for conversion may help the surgeon to better select patients, reduce conversion, and to better counsel patients on the risks of such an event. In this study, we identified dyspnea, PPPD, laparoscopic approach, and multivisceral and vascular resection as important predictors

Table 2 Unadjusted perioperative outcomes of robotic and laparoscopic cases

	Laparoscopic PD	Robotic PD	*p* value
Total patients (%)	235 (54.9)	193 (45.1)	
Mean (median)			
Operative time (minutes)	429 (424)	422 (399)	0.588
Length of stay (days)	10.6 (7.0)	10.7 (8.0)	0.904
Frequency (%)			
Return to operating room	18 (7.7)	13 (6.7)	0.714
30-day mortality	6 (2.6)	2(1.0)	0.303[a]
Readmission	38 (16.2)	43(22.3)	0.108
Discharge to nonhome	20 (8.7)	20 (10.5)	0.544
Conversion	61 (26.0)	22 (11.4)	< 0.001
Overall complication	115 (48.9)	106 (54.9)	0.218
Major complication	96 (40.9)	81 (42.0)	0.815
Superficial SSI	9 (3.8)	18 (9.3)	0.020
Deep SSI	2 (0.9)	4 (2.1)	0.416[a]
Organ space SSI	30 (12.8)	28 (14.5)	0.600
Dehiscence	5 (2.1)	1 (0.5)	0.229[a]
Pneumonia	8 (3.4)	2 (1.0)	0.196[a]
Unplanned intubation	12 (5.1)	8 (4.1)	0.639
Pulmonary embolism	4 (1.7)	4 (2.1)	> 0.999[a]
Ventilator for > 48 h	11 (4.7)	5 (2.6)	0.257
Acute renal failure	2 (0.9)	2 (1.0)	> 0.999
Urinary tract infection	5 (2.1)	9 (4.7)	0.142
Cardiac arrest	5 (2.1)	1 (0.5)	0.229[a]
Bleeding requiring transfusion	44 (18.7)	27 (14.0)	0.190
Transfusion day 0	34 (14.5)	23 (11.9)	
Transfusion ≥ day 1	10 (4.3)	4 (2.0)	
DVT/thrombophlebitis	7 (3.0)	5 (2.6)	0.809
Sepsis/septic shock	23 (9.8)	18 (9.3)	0.872
Pancreatic fistula			
None	189(81.1)	152 (79.2)	0.075
Without intervention	24 (10.3)	31 (16.1)	
With intervention	20 (8.6)	9 (4.7)	
Delayed gastric emptying	43 (18.6)	28 (14.6)	0.269

DVT deep vein thrombosis, *PD* pancreaticoduoedenectomy, *SSI* surgical site infection

[a] Fischer's test

of conversion. The advantage of using a national database is the ability to determine the adjusted odds of conversion for the different risk factors due to the presence of a relatively large number of conversions; however, we could not identify the exact causes for conversion in this dataset, such as bleeding, as that level of detail is not captured in NSQIP.[27] Several factors may be involved in conversion. Vascular and multivisceral resections can pose challenges when completing the operation in a minimally invasive fashion and are usually associated with locally advanced disease, leading to a difficult dissection. Having pulmonary disease has been previously associated with a higher conversion in other minimally invasive operations and it may correlate with poor pulmonary reserve, leading to an inability to tolerate pneumoperitoneum.[28,29] Interestingly, PPPD was associated with a higher conversion rate, which may be due to the need for a more challenging gastrojejunal anastomosis. The use of a robot may facilitate the performance of the complex reconstructions needed in PD and the control of bleeding due to improved ergonomics, dexterity, and better visualization in comparison to laparoscopy, explaining the lower rate of conversion.

This study was limited by its retrospective design and its relatively small sample size, preventing a more robust analysis, such as propensity matching, which would allow us to adjust for all known and clinically important confounders

Table 3 Multivariable analysis determining predictors of overall complication

	Univariate OR	Univariate *p* value	Multivariable OR (95% CI)
Gender			
Male	Ref		
Female	0.71	0.073	
Age (mean, SD; years)	1.01	0.370	
Race			
White	Ref		
African American	1.79	0.108	
Others/unknown	0.81	0.563	
Body mass index (mean, SD; kg/m^2)[a]	1.05	0.002	1.05 (1.01–1.08)
Obstructive jaundice	0.78	0.209	
Weight loss > 10%	1.07	0.832	
ASA class			
Class I	Ref		
Class II	0.34	0.367	
Class III	0.33	0.338	
Class IV	1.67	0.698	
Diabetes mellitus	1.36	0.184	
Hypertension	1.54	0.027	
Dyspnea	1.92	0.199	
Diagnosis group			
≤ 5 cm, benign	Ref		
> 5 cm, benign	0.65	0.517	
T0–T2, malignant	0.93	0.821	
T3–T4, malignant	0.75	0.331	
Pancreatitis	1.34	0.592	
Neoadjuvant chemotherapy	0.92	0.745	
Neoadjuvant radiotherapy	1.01	0.981	
Surgery type			
Whipple	Ref	0.621	
PPPD	0.89		
Vascular resection	2.35	0.001	2.28 (1.33–3.90)
Multivisceral resection	1.90	0.071	
Intraoperative drains	1.49	0.398	
Approach			
Laparoscopic	Ref		
Robotic	1.27	0.218	
Operative time[a]	1.003	0.001	1.002 (1.001–1.004)

ASA American Society of Anesthesiologists, *CI* confidence interval, *OR* odds ratio, *PPPD* pylorus-preserving pancreaticoduodenectomy, *SD* standard deviation

[a] Continuous variable

and subsequently let us compare all outcomes between both groups. Instead we chose two important outcomes—30-day overall complication and conversion rates—and determined their independent association with the robotic or laparoscopic surgical approach using logistic regression and adjusting for other important factors. Thus, caution should be taken when comparing both approaches with regard to the other unadjusted outcomes, as the groups were imbalanced at baseline. In addition, the NSQIP database lacks information on surgeon and hospital volumes of pancreatic surgery in general, and MIPD specifically, and therefore we could not determine where the surgeons performing these operations were in their learning curves. This is important, as MIPD is associated with a steep learning curve and requires performing at least

Table 4 Multivariable analysis determining predictors of conversion of minimally invasive pancreaticoduodenectomy

	Nonconverted, *n* (%)	Converted, *n* (%)	Univariate *p* value	Multivariable OR (95% CI)
Total patients	345 (80.6)	83 (19.4)		
Gender				
Female	166 (48.1)	32 (38.6)	0.117	
Male	179 (51.9)	51 (61.4)		
Age (mean, SD; years)	63.3 (12.1)	64.0 (9.9)	0.641	
Race			0.810	
White	285 (82.6)	71 (85.5)		
African American	31 (9.0)	6 (7.2)		
Others/unknown	29 (8.4)	6 (7.2)		
Body mass index (mean, SD; kg/m^2)	27.5 (6.0)	28.4 (6.3)	0.231	
Obstructive jaundice	140 (40.6)	37 (44.6)	0.507	
Weight loss			0.565	
≤ 10% loss	307 (89.0)	72 (86.7)		
> 10% loss	38 (11.0)	11 (13.3)		
ASA class			0.425	
Class I/II	85 (24.6)	17 (20.5)		
Class III/IV	260 (75.4)	66 (79.5)		
Diabetes mellitus	78 (22.6)	23 (27.7)	0.326	
Hypertension	168 (48.7)	48 (57.8)	0.135	
Dyspnea	9 (2.6)	9 (10.8)	0.003[a]	4.56 (1.63–12.74)
Diagnosis group			0.707	
≤ 5 cm, benign	47 (13.6)	10 (12.0)		
> 5 cm, benign	10 (2.9)	1 (1.2)		
T0–T2, malignant	74 (21.4)	20 (24.1)		
T3–T4, malignant	197 (57.1)	50 (60.2)		
Pancreatitis	17 (4.9)	2 (2.4)		
Neoadjuvant chemotherapy	68 (19.7)	12 (14.5)	0.270	
Neoadjuvant radiotherapy	22 (6.4)	5 (6.0)	0.906	
Surgery type			0.045	
Whipple	269 (78.0)	56 (67.5)		Ref
PPPD	76 (22.0)	27 (32.5)		2.42 (1.33–4.39)
Multivisceral resection	22 (6.4)	16 (19.3)	< 0.001	2.86 (1.32–6.23)
Vascular resection	43 (12.5)	36 (43.4)	< 0.001	5.30 (2.97–9.45)
Intraoperative drains	331 (95.9)	78 (94.0)	0.435	
Approach			< 0.001	
Laparoscopic	174 (50.4)	61 (73.5)		Ref
Robotic	171 (49.6)	22 (26.5)		0.46 (0.26–0.81)

ASA American Society of Anesthesiologists, *CI* confidence interval, *OR* odds ratio, *PPPD* pylorus-preserving pancreaticoduoedenectomy, *SD* standard deviation

[a] Fischer's test

80 cases to reduce operative time and 20 cases to reduce conversion.[30] Finally, we could not assess the oncological outcomes between both operations as the NSQIP database does not provide pathological variables or survival data; therefore, such an analysis would be best performed from other cancer-targeted prospective databases.

Conclusions

RPD was associated with a lower rate of conversion than LPD and a similar 30-day overall complication rate. This report suggests that both minimally invasive approaches have similar outcomes with regard to postoperative complications.

Prospective evaluation is needed to corroborate these findings. Adopting one approach versus the other should be based on objective data, and more importantly, on the experience of the surgeon with the minimally invasive platform used.

Acknowledgements Research reported in this publication was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health under award number UL1TR001105. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. They would like to thank Dave Primm for his help in editing this manuscript and Helen Mayo from the UT Southwestern Health Sciences Digital Library and Learning Center for assistance with literature searches. RMM is the Alvin Baldwin, Jr. Chair in surgery. MRP is the Dedman Family Scholar in clinical care. SCW is a UT Southwestern Disease-Oriented Clinical Scholar.

Author Contributions I. Nassour and R. Minter: study design, data analysis and interpretation, writing initial draft, and revising and approving the final draft; S. Wang, P. Polanco, M. Augustine, J. Mansour, M. Porembka, A. Yopp, M. Choti: data interpretation and revising and approving the final draft.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Source of Funding The National Center for Advancing Translational Sciences of the National Institutes of Health under award number UL1TR001105.

References

1. Cameron JL, Riall TS, Coleman J, Belcher KA. One thousand consecutive pancreaticoduodenectomies. Ann Surg. 2006;244:10–15.
2. Dokmak S, Ftériche FS, Aussilhou B, Bensafta Y, Lévy P, Ruszniewski P, Belghiti J, Sauvanet A. Laparoscopic pancreaticoduodenectomy should not be routine for resection of periampullary tumors. J Am Coll Surg. 2015;220:831–838.
3. Song KB, Kim SC, Hwang DW, Lee JH, Lee DJ, Lee JW, Park KM, Lee YJ. Matched case-control analysis comparing laparoscopic and open pylorus-preserving pancreaticoduodenectomy in patients with periampullary tumors. Ann Surg. 2015;262:146–155.
4. Tran TB, Dua MM, Worhunsky DJ, Poultsides GA, Norton JA, Visser BC. The first decade of laparoscopic pancreaticoduodenectomy in the United States: costs and outcomes using the nationwide inpatient sample. Surg Endosc. 2016;30:1778–1783.
5. Adam MA, Choudhury K, Dinan MA, Reed SD, Scheri RP, Blazer DG 3rd, Roman SA, Sosa JA. Minimally invasive versus open pancreaticoduodenectomy for cancer: practice patterns and short-term outcomes among 7061 patients. Ann Surg. 2015;262:372–377.
6. Croome KP, Farnell MB, Que FG, Reid-Lombardo KM, Truty MJ, Nagorney DM, Kendrick ML. Total laparoscopic pancreaticoduodenectomy for pancreatic ductal adenocarcinoma. Ann Surg. 2014;260:633–640.
7. Sharpe SM, Talamonti MS, Wang CE, Prinz RA, Roggin KK, Bentrem DJ, Winchester DJ, Marsh RD, Stocker SJ, Baker MS. Early national experience with laparoscopic pancreaticoduodenectomy for ductal adenocarcinoma: a comparison of laparoscopic pancreaticoduodenectomy and open pancreaticoduodenectomy from the National Cancer Data Base. J Am Coll Surg. 2015;221:175–184.
8. Baker EH, Ross SW, Seshadri R, Swan RZ, Iannitti DA, Vrochides D, Martinie JB. Robotic pancreaticoduodenectomy: comparison of complications and cost to the open approach. Int J Med Robot. 2016;12:554–560.
9. Stauffer JA, Coppola A, Villacreses D, Mody K, Johnson E, Li Z, Asbun HJ. Laparoscopic versus open pancreaticoduodenectomy for pancreatic adenocarcinoma: long-term results at a single institution. Surg Endosc. 2016;31:1–9.
10. Zureikat AH, Postlewait LM, Liu Y, Gillespie TW, Weber SM, Abbott DE, Ahmad, SA, Maithel SK, Hogg ME, Zenati M, Cho CS, Salem A, Xia B, Steve J, Nguyen TK, Keshava HB, Chalikonda S, Walsh RM, Talamonti MS, Stocker SJ, Bentrem DJ, Lumpkin S, Kim HJ, Zeh HJ 3rd, Kooby DA. A multi-institutional comparison of perioperative outcomes of robotic and open pancreaticoduodenectomy. Ann Surg. 2016;264:640–649.
11. Tee MC, Croome KP, Shubert CR, Farnell MB, Truty MJ, Que FG, Reid-Lombardo KM, Smoot RL, Nagorney DM, Kendrick ML. Laparoscopic pancreatoduodenectomy does not completely mitigate increased perioperative risks in elderly patients. HPB (Oxford). 2015;17:909–918.
12. McMillan MT, Zureikat AH, Hogg ME, Kowalsky SJ, Zeh HJ, Sprys MH, Vollmer CM, Jr. A propensity score-matched analysis of robotic vs open pancreatoduodenectomy on incidence of pancreatic fistula. JAMA Surg. 2017;152(4):327–335.
13. Asbun HJ, Stauffer JA. Laparoscopic vs open pancreaticoduodenectomy: overall outcomes and severity of complications using the Accordion Severity Grading System. J Am Coll Surg. 2012;215:810–819.
14. Nassour I, Wang SC, Christie A, Augustine MM, Porembka MR, Yopp AC, Choti MA, Mansour JC, Xie XJ, Polanco PM, Minter RM. Minimally invasive versus open pancreaticoduodenectomy: a propensity-matched study from a national cohort of patients. Ann Surg. 2017. **[Epub ahead of print]**
15. Zhang H, Wu X, Zhu F, Shen M, Tian R, Shi C, Wang X, Xiao G, Guo X, Wang M, Qin R. Systematic review and meta-analysis of minimally invasive versus open approach for pancreaticoduodenectomy. Surg Endosc. 2016;30:5173–5184.
16. Wang M, Cai H, Meng L, Cai Y, Wang X, Li Y, Peng B. Minimally invasive pancreaticoduodenectomy: a comprehensive review. Int J Surg. 2016;35:139–146.
17. Doula C, Kostakis ID, Damaskos C, Machairas N, Vardakostas DV, Feretis T, Felekouras E. Comparison between minimally invasive and open pancreaticoduodenectomy: a systematic review. Surg Laparosc Endosc Percutan Tech. 2016;26:6–16.
18. Correa-Gallego C, Dinkelspiel HE, Sulimanoff I, Fisher S, Viñuela EF, Kingham, TP, Fong Y, DeMatteo RP, D'Angelica MI, Jarnagin WR, Allen PJ. Minimally-invasive vs open pancreaticoduodenectomy: systematic review and meta-analysis. J Am Coll Surg. 2014;218:129–139.
19. Liu R, Zhang T, Zhao ZM, Tan XL, Zhao GD, Zhang X, Xu Y. The surgical outcomes of robot-assisted laparoscopic pancreaticoduodenectomy versus laparoscopic pancreaticoduodenectomy for periampullary neoplasms: a comparative study of a single center. Surg Endosc. 2017;31:2380–2386.
20. Wright GP, Zureikat AH. Development of minimally invasive pancreatic surgery: an evidence-based systematic review of laparoscopic versus robotic approaches. J Gastrointest Surg. 2016;20:1658–1665.
21. American College of Surgeons. User Guide for the 2015 ACS NSQIP Procedure Targeted Participant Use Data File (PUF). https://www.facs.org/~/media/files/quality%20programs/nsqip/pt_nsqip_puf_user_guide_2015.ashx. Accessed December 12, 2016.

22. Leow JJ, Heah NH, Chang SL, Chong YL, Png KS. Outcomes of robotic versus laparoscopic partial nephrectomy: an updated meta-analysis of 4,919 Patients. J Urol. 2016;196:1371–1377.
23. Xie W, Cao D, Yang J, Shen K, Zhao L. Robot-assisted surgery versus conventional laparoscopic surgery for endometrial cancer: a systematic review and meta-analysis. J Cancer Res Clin Oncol. 2016;142:2173–2183.
24. Kim CW, Kim CH, Baik SH. Outcomes of robotic-assisted colorectal surgery compared with laparoscopic and open surgery: a systematic review. J Gastrointest Surg. 2014;18:816–830.
25. Park JM, Kim HI, Han SU, Yang HK, Kim YW, Lee HJ, An JY, Kim MC, Park S, Song KY, Oh SJ, Kong SH, Suh BJ, Yang DH, Ha TK, Hyung WJ, Ryu KW. Who may benefit from robotic gastrectomy? A subgroup analysis of multicenter prospective comparative study data on robotic versus laparoscopic gastrectomy. Eur J Surg Oncol. 2016;42:1944–1949.
26. Daouadi M, Zureikat AH, Zenati MS, Choudry H, Tsung A, Bartlett DL, Hughes SJ, Lee KK, Moser AJ, Zeh HJ. Robot-assisted minimally invasive distal pancreatectomy is superior to the laparoscopic technique. Ann Surg. 2013;257:128–132.
27. Zureikat AH, Borrebach J, Pitt HA, Mcgill D, Hogg ME, Thompson V, Bentrem DJ, Hall BL, Zeh HJ. Minimally invasive hepatopancreatobiliary surgery in North America: an ACS-NSQIP analysis of predictors of conversion for laparoscopic and robotic pancreatectomy and hepatectomy. HPB (Oxford). 2017;19(7):595–602.
28. Sippey M, Grzybowski M, Manwaring ML, Kasten KR, Chapman WH, Pofahl WE, Pories WJ, Spaniolas K. Acute cholecystitis: risk factors for conversion to an open procedure. J Surg Res. 2015;199:357–361.
29. Bhama AR, Charlton ME, Schmitt MB, Cromwell JW, Byrn JC. Factors associated with conversion from laparoscopic to open colectomy using the National Surgical Quality Improvement Program (NSQIP) database. Colorectal Dis. 2015;17:257–264.
30. Boone BA, Zenati M, Hogg ME, Steve J, Moser AJ, Bartlett DL, Zeh HJ, Zureikat AH. Assessment of quality outcomes for robotic pancreaticoduodenectomy: identification of the learning curve. JAMA Surg. 2015;150:416–422.