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ORIGINAL SCIENTIFIC REPORT

Minimally Invasive Distal Pancreatectomy for Cancer: Short-Term Oncologic Outcomes in 1733 Patients

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Abstract

Background Data from high-volume institutions suggest that minimally invasive distal pancreatectomy (MIDP) provides favorable perioperative outcomes and adequate oncologic resection for pancreatic cancer; however, these outcomes may not be generalizable. This study examines patterns of use and short-term outcomes from MIDP (laparoscopic or robotic) versus open distal pancreatectomy (ODP) for pancreatic adenocarcinoma in the United States.

Methods Adult patients undergoing distal pancreatectomy were identified from the National Cancer Database, 2010–2011. Multivariable modeling was applied to compare short-term outcomes from MIDP versus ODP for pancreatic adenocarcinoma.

Results 1733 patients met inclusion criteria: 535 (31 %) had MIDP and 1198 (69 %) ODP. Use of MIDP increased 43 % between 2010 and 2011; the conversion rate from MIDP to ODP was 23 %. MIDP cases were performed at 215 hospitals, with 85 % of hospitals performing <10 cases overall. After adjustment, pancreatic adenocarcinoma patients undergoing MIDP versus ODP had a similar likelihood of complete resection (OR 1.48, $p = 0.10$), number of lymph nodes removed (RR 1.01, $p = 0.91$), and 30-day readmission rate (OR 1.02, $p = 0.96$); however, length of stay was shorter (RR 0.84, $p < 0.01$).

Conclusions Use of MIDP for cancer is increasing, with most centers performing a low volume of these procedures. Use of MIDP for body and tail pancreatic adenocarcinoma appears to have short-term outcomes that are similar to those of open procedures with the benefit of a shorter hospital stay. Larger studies with longer follow-up are needed.

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Introduction

Minimally invasive surgical techniques have been introduced in different surgical specialties, usually with improved postoperative outcomes, shorter length of hospital stay, and faster recovery [1, 2]. They have become a routine part of the management for some abdominal cancers [3, 4]. However, adoption of minimally invasive techniques for pancreatic surgery has lagged behind. While the first minimally invasive pancreatic procedure was reported in the mid-1990s [5], at least a decade had passed until institutional reports suggested there was increasing interest in minimally invasive pancreatectomy [6–8]. This is likely due to the perceived technical difficulty associated with minimally invasive pancreatic surgery, in part due to the retroperitoneal location of the pancreas, its proximity to major vascular structures, and the potential for pancreatic fistula [5].

Concerns have been raised regarding the oncologic adequacy of surgical resections performed via minimally invasive approaches for pancreatic cancer [9, 10]. Published data examining oncologic outcomes from minimally invasive versus open distal pancreatectomy (ODP) for pancreatic tumors have demonstrated improved short-term outcomes without attendant concern about oncologic safety [6, 8, 11]. However, these data are limited to clinical series reported from high-volume institutions, where the procedure is typically performed by high-volume pancreatic surgeons. As a result, these favorable outcomes may not be generalizable to lower-volume centers [12–14].

We sought to examine practice patterns surrounding utilization of minimally invasive distal pancreatectomy (MIDP) in order to compare short-term oncologic outcomes compared to ODP for pancreatic adenocarcinoma in the United States. We hypothesized that MIDP compared to open surgery is associated with improved short-term outcomes and similar rates of complete oncologic resection.

Materials and methods

The National Cancer Data Base (NCDB) is a joint program of the Commission on Cancer (CoC) of the American Cancer Society and the American College of Surgeons. The NCDB is a large, nationwide, clinical surveillance database. Data are collected from >1500 CoC-accredited cancer centers representing 70 % of newly diagnosed cancer cases in the United States [15].

The data coding process is according to the CoC Registry Operations and Data Standards Manual, the American Joint Committee for Cancer (AJCC) Manual for Staging of Cancer, and the International Classification of Diseases for Oncology, Third Edition (ICD-O3). All data were extracted from medical records by trained and certified tumor registrars. This study was granted exempt status from our institutional Review Board.

Patients undergoing minimally invasive (defined as laparoscopic and robotic) distal pancreatectomy or open distal pancreatic surgery for pancreatic tumors were identified from the NCDB Participant User File, 2010–2011. The following variables were extracted from the dataset: patient age, gender, race, annual income, insurance status, year of diagnosis, comorbidities, location and type of the treating hospital, histological diagnosis, stage of disease, location of the tumor within the pancreas, and extent of resection. The NCDB determines annual income by linking a patient's ZIP code to year 2000 United States Census data. Data on comorbidities were represented by Charlson/Deyo scores [16]. The NCDB defines hospitals as community (accession 100–500 new cancer cases/year), comprehensive community (accession > 500 new cancer cases/year), or academic centers (accession > 500 new cancer cases/year; provide postgraduate medical education, research, and clinical trials) [15]. Patients were excluded if they underwent local excision, or if extent of surgical resection was not specified.

Short-term outcomes extracted from the dataset included number of lymph nodes removed, surgical margin status, length of hospital stay, incidence of unplanned readmissions within 30 days of surgical discharge, and 30-day mortality.

Statistical analysis

The study cohort was allocated into two treatment groups: patients who had MIDP and those who underwent ODP. Intention-to-treat analysis was employed, such that minimally invasive cases that were converted to open were analyzed as minimally invasive cases.

Patient demographic, clinical, and tumor characteristics were compared between the minimally invasive versus open surgery groups using Fisher's exact/Chi square and Kruskal–Wallis tests. Multivariable logistic regression models were used to analyze factors independently associated with the use of minimally invasive versus ODP; a backward variable elimination method was used to produce the most parsimonious and fit model by removal of non-significant variables based on a cutoff p value of ≤ 0.2.

Short-term outcomes were compared between minimally invasive versus ODP using multivariable regression analyses, while adjusting for patient age, gender, race, comorbidities, cancer stage (derived from combining clinical and pathological AJCC staging systems), location of tumor within the pancreas, hospital type, and hospital volume of minimally invasive procedures performed over the 2-year study period. The interaction of surgical approach and hospital volume was not included in the models, as it was not significant. Logistic regression modeling was used to analyze dichotomous outcome variables such as rate of positive surgical margins, readmission rates, and 30-day mortality, while negative binomial regression modeling was used to analyze length of stay and number of lymph nodes removed. Since length of stay and number of lymph nodes removed were over-dispersed, we applied negative binomial regression to analyze these two outcomes. Generalized estimating equations [17] were used with each of the multivariable models to account

Table 1 Demographic and clinical characteristics of patients undergoing minimally invasive distal pancreatectomy versus open distal pancreatectomy, NCDB 2010–2011

	Minimally invasive ($N = 535$)	Open ($N = 1198$)	p value
Patient age (mean ± SD, years)	64 ± 13	63 ± 14	0.09
Male gender	276 (52 %)	575 (48 %)	0.18
Race			
White	447 (84 %)	981 (82 %)	
Black	62 (12 %)	155 (13 %)	
Other	15 (3 %)	34 (3 %)	
Annual income			0.17
<$35,000	132 (25 %)	332 (28 %)	
≥$35,000	368 (69 %)	783 (65 %)	
Insured	526 (100 %)	1159 (97 %)	0.009
Charlson/Deyo score			0.95
0	337 (63 %)	764 (64 %)	
1	151 (28 %)	333 (28 %)	
≥ 2	47 (9 %)	101 (8 %)	
Hospital type			<0.0001
Academic	360 (67 %)	667 (56 %)	
Comprehensive community	159 (30 %)	480 (40 %)	
Community	15 (3 %)	49 (4 %)	
U.S. geographic region			0.002
South	195 (37 %)	459 (38 %)	
Northeast	155 (29 %)	265 (22 %)	
Midwest	139 (26 %)	314 (26 %)	
West	46 (9 %)	160 (13 %)	
Year of diagnosis			<0.0001
2010	220 (41 %)	624 (52 %)	
2011	315 (59 %)	574 (48 %)	
Histology			0.0002
Adenocarcinoma	267 (50 %)	708 (59 %)	
NET	221 (41 %)	375 (31 %)	
Other	31 (6 %)	82 (7 %)	
Tumor location			0.006
Tail	403 (75 %)	825 (69 %)	
Body	132 (25 %)	373 (31 %)	
Tumor size (cm)	3.6 ± 2.2	4.3 ± 4.1	0.0005
Stage			0.16
I	211 (40 %)	455 (39 %)	
II	277 (53 %)	591 (51 %)	
III	*	23 (2 %)	
IV	28 (5 %)	98 (8 %)	
Conversion lap to open	122 (23 %)	–	

Values are presented as percentages of given sample size. Percentages were rounded and may not add to 100 due to missing values

NCDB National Cancer Data Base, *SD* standard deviation, *NET* neuroendocrine tumor, *NOS* not otherwise specified

* Suppressed due to small cell size, per NCDB policy

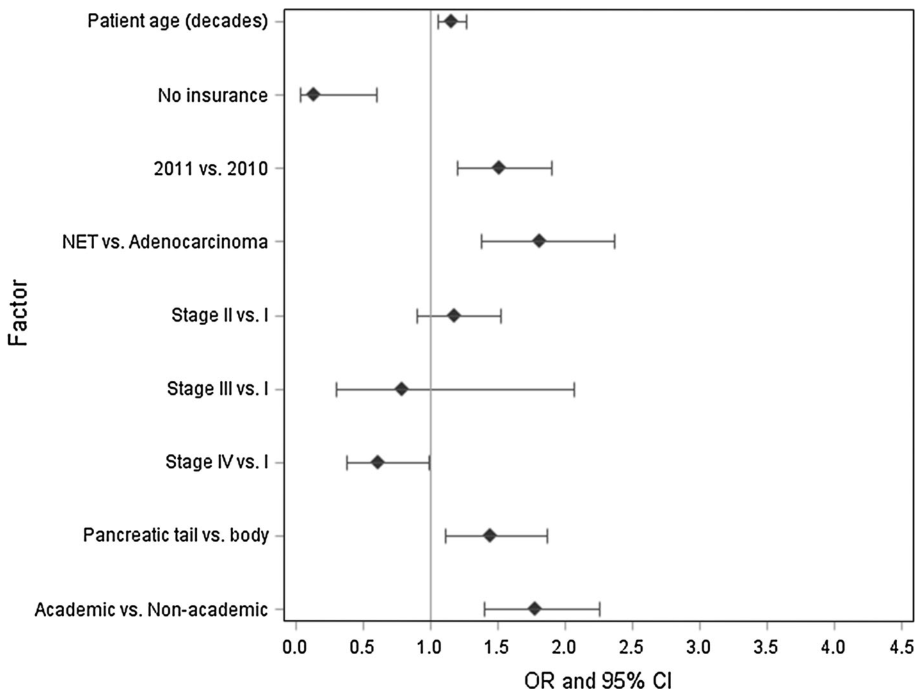

Fig. 1 Factors independently associated with the likelihood of undergoing minimally invasive distal pancreatectomy versus open distal pancreatectomy. *Black diamonds* represent odds ratios for the independent association of each factor with using minimally invasive distal pancreatectomy; 95 % confidence interval (CI) bounds are represented by the corresponding *horizontal lines*. Factors on the *right* of the *vertical line* at 1.0 are independently associated with using minimally invasive surgery

for clustering of patients within hospitals. The level of statistical significance was set a priori at a two-sided p value of <0.05. Statistical analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC).

Results

A total of 1733 patients underwent distal pancreatectomy for body and tail pancreatic tumors; the majority of patients had pancreatic adenocarcinoma (56 %), while one-third (34 %) had pancreatic neuroendocrine tumors. Of all cases, 535 (31 %) patients underwent MIDP, and 1198 (69 %) patients had open surgery. Conversion from minimally invasive to ODP occurred in 122 cases (23 %). During the study period, use of minimally invasive techniques increased by 43 %, from 220 cases in 2010 to 315 cases in 2011 ($p < 0.01$).

Patient age, gender, race, and comorbidities were not statistically different between the minimally invasive and open groups (Table 1). Compared to patients in the open group, those undergoing minimally invasive surgery were more often insured (97 vs. 100 %) and had a neuroendocrine diagnosis (31 vs. 41 %); tumors were more likely to be located in the tail of the pancreas (69 vs. 75 %), and were smaller (mean 4.3 vs. 3.6 cm), respectively (all $p < 0.01$). Patients who underwent conversion from laparoscopic or robotic to open procedures were more often found to have multiple comorbidities (13 vs. 7 %, $p = 0.01$), adenocarcinoma (61 vs. 47 %, $p = 0.02$), larger tumors (3.9 vs. 3.5 cm, $p = 0.02$), more advanced tumor stage, and positive margins (14 vs. 8 %, $p = 0.077$).

Factors independently associated with using minimally invasive versus ODP were older patient age, a diagnosis of a neuroendocrine tumor, tumor location in the pancreatic tail, and treatment at an academic center and in 2011 (vs. 2010). Lack of insurance and advanced tumor stage were negatively associated with use of minimally invasive surgery (Fig. 1).

Short-term outcomes

Outcomes from minimally invasive versus ODP then were examined in the 975 patients with pancreatic adenocarcinoma. In unadjusted analysis, patients undergoing minimally invasive versus ODP were more likely to have complete tumor resections (86 vs. 81 %, respectively, $p = 0.002$) and a shorter hospital length of stay (mean 7 vs. 9 days, $p < 0.0001$). The number of lymph nodes removed and rates of unplanned 30-day readmissions and 30-day mortality were not different between the two treatment groups (Table 2).

After adjustment for patient demographic, clinical, and tumor characteristics, minimally invasive versus ODP for pancreatic adenocarcinoma was associated with a significantly shorter hospital length of stay (relative reduction (RR) 0.84, 95 % confidence interval (CI) 0.79–0.91, $p < 0.0001$). However, there were no differences between

Table 2 Unadjusted outcomes from minimally invasive distal pancreatectomy versus open distal pancreatectomy, NCDB 2010–2011

	Minimally invasive ($N = 535$)	Open ($N = 1198$)	p value
Complete surgical resection	217 (86 %)	533 (81 %)	0.12
Number of LNs (mean ± SD)	15 ± 10	13 ± 9	0.06
LOS (mean ± SD, days)	7 ± 5	9 ± 6	<0.0001
Unplanned 30-day readmission	27 (11 %)	56 (9 %)	0.37
30-day mortality	*	11 (2 %)	0.59

NCDB National Cancer Data Base, *LNs* lymph nodes, *SD* standard deviation, *LOS* length of stay

* Suppressed due to small cell size, per NCDB policy

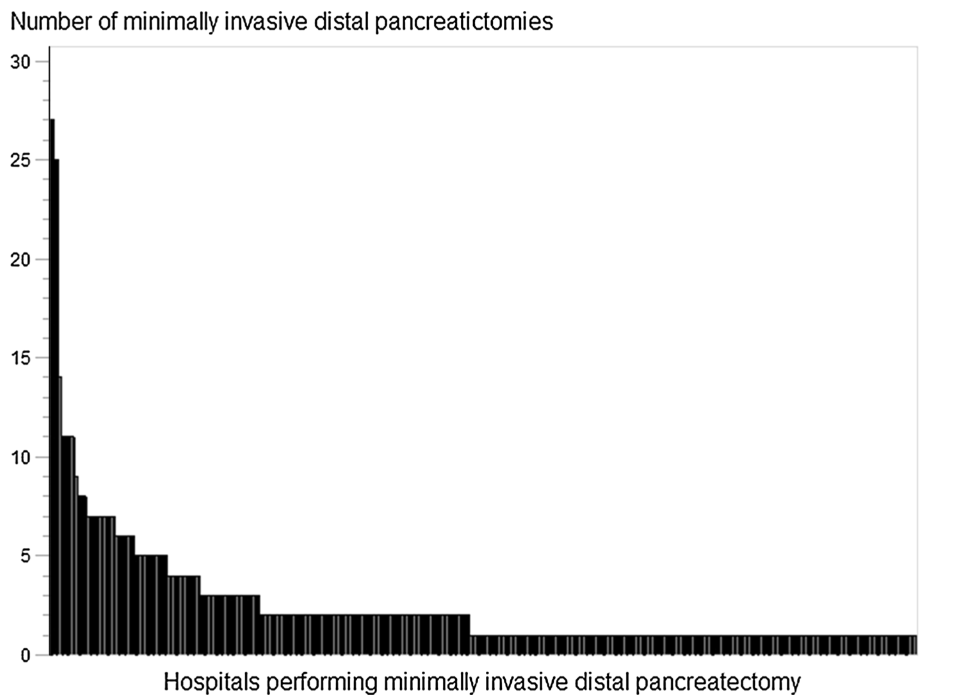

Fig. 2 Case volume among hospitals performing minimally invasive distal pancreatectomy for cancer (2010–2011). Each *bar* represents a hospital that performed at least 1 case of minimally invasive distal pancreatectomy

minimally invasive and ODP with regard to the likelihood of complete tumor resection (OR 1.48, CI 0.93–2.34, $p = 0.10$), number of lymph nodes removed (RR 1.01, CI 0.88–1.15, $p = 0.91$), or unplanned 30-day readmissions (OR 1.02, CI 0.55–1.87, $p = 0.96$).

Hospital procedural volume

Over the 2-year study period, the number of MIDP cases performed by each hospital ranged from 1 to 27 cases, with a median of 3 cases. There were 215 hospitals that performed MIDP, with the overwhelming majority of cases (85 %) reported at hospitals that performed <10 cases over the 2-year study period (Fig. 2). Compared to high-volume hospitals, low-volume hospitals were more likely to perform minimally invasive resections for adenocarcinoma patients who presented with distant metastases (0 vs. 6 %, $p = 0.13$); tumor resections at low-volume hospitals were more often incomplete based on the presence of positive surgical margins (6 vs. 19 %, $p = 0.048$) and include fewer lymph nodes in the resection specimen (mean 19 vs. 13, $p < 0.0001$), respectively (Table 3).

Subset analysis

In all analyses, patients undergoing laparoscopic and robotic distal pancreatectomy were combined in the minimally invasive group. We performed a subset analysis to explore similarities between the laparoscopic and robotic groups. The two groups were similar with regard to patient demographics, comorbidities, pathological characteristics, and outcomes (Table 4).

Table 3 Characteristics of patients undergoing minimally invasive distal pancreatectomy for pancreatic adenocarcinoma by minimally invasive hospital procedural volume

	High-volume (≥10 cases/2 years) ($N = 52$)	Low (<10 cases/2 years) ($N = 215$)	p
Patient age (mean ± SD, years)	67 ± 10	69 ± 10	0.75
Male gender	26 (50 %)	120 (56 %)	0.54
Race			0.24
White	43 (83 %)	176 (82 %)	
Non-white	*	36 (17 %)	
Charlson/Deyo score			0.77
0	27 (52 %)	114 (53 %)	
1	16 (31 %)	72 (34 %)	
≥2	*	29 (13 %)	
Hospital type			<0.0001
Academic	52 (100 %)	126 (59 %)	
Non-academic	0	89 (41 %)	
Tumor size (cm, mean ± SD)	3.8 ± 1.9	4.0 ± 2.1	0.34
Distance traveled (miles, mean ± SD)	146 ± 308	36 ± 86	<0.0001
Distant metastases at diagnosis	0	12 (6 %)	0.13
Tumor location			0.005
Tail	29 (56 %)	164 (76 %)	
Body	23 (44 %)	51 (24 %)	
Conversion to open	13 (25 %)	61 (28 %)	0.73
Complete surgical resection (R0)	49 (94 %)	175 (83 %)	0.048
Number of LNs (mean ± SD)	19 ± 11	13 ± 9	<0.0001
LOS (mean ± SD, days)	7 ± 5	8 ± 6	0.47
Unplanned 30-day readmission	*	24 (11 %)	0.62

Values are presented as percentages of given sample size. Percentages were rounded and may not add to 100 due to missing values

LNs lymph nodes, *SD* standard deviation, *LOS* length of stay

* Suppressed due to small cell size, per NCDB policy

Discussion

This nationally representative study examined current practice patterns and short-term oncologic outcomes associated with MIDP for cancer in the United States. Minimally invasive approaches were used in 31 % of all distal pancreatic tumor resections in the United States in 2010–2011. The number of minimally invasive distal pancreatectomies increased over the study period, with the vast majority of cases performed at low-volume institutions. MIDP for adenocarcinoma appears to have rates of complete tumor resection and 30-day readmissions that are similar to those associated with open pancreatectomy. However, minimally invasive surgery is associated with a shorter hospital length of stay.

Recently, there has been a significant increase in the number of published series of MIDP, suggesting increasing interest and utilization [6, 8, 10]. In a meta-analysis of 1814 patients pooled from 18 studies, Venkat et al. found that MIDP techniques were used in 43 % of all distal pancreatic resections for benign and malignant disease [10]. In a population-based study from the Nationwide Inpatient Sample (HCUP-NIS), Tran Cao et al. examined temporal trends of MIDP from 1998 to 2009. The study included 8957 patients who had distal pancreatectomy for different benign and malignant conditions. Overall, minimally invasive surgery was used in 4.3 % of all distal pancreatectomies; however, they found a significant trend over time toward using minimally invasive surgery, which tripled from 2.4 % of all distal pancreatectomies in 1998 to 7.3 % in 2009 [12]. The rate of MIDP in our study was 31 % compared to 4 % in the Tran Cao et al.'s study. The more recent nature of our cohort (2010–2011), along with the increasing utilization of minimally invasive techniques over time, likely explains this difference. The NCDB may also be more nationally representative, capturing at least 70 % of new cancer cases across the country [15]. A subsequent report from the HCUP-NIS and the American

Table 4 Patient characteristics and outcomes of patients undergoing laparoscopic versus robotic distal pancreatectomy, NCDB 2010–2011

	Laparoscopic ($n = 474$)	Robotic ($n = 61$)	p value
Patient age (mean ± SD, years)	64 ± 13	65 ± 14	0.55
Male gender	248 (52 %)	28 (46 %)	0.41
Race			0.69
White	399 (84 %)	48 (79 %)	
Black	53 (11 %)	*	
Other	18 (4 %)	*	
Annual income			0.53
<$35,000	119 (25 %)	13 (21 %)	
≥$35,000	323 (68 %)	45 (74 %)	
Insured	468 (99 %)	58 (95 %)	1
Charlson/Deyo score			0.76
0	296 (62 %)	41 (67 %)	
1	136 (29 %)	15 (25 %)	
≥2	42 (9 %)	*	
Hospital type			0.25
Academic	312 (66 %)	48 (79 %)	
Comprehensive community	147 (31 %)	12 (20 %)	
Community	14 (3 %)	*	
U.S. geographic region			0.002
South	183 (39 %)	12 (20 %)	
Northeast	125 (26 %)	30 (49 %)	
Midwest	125 (26 %)	14 (23 %)	
West	41 (9 %)	*	
Histology			0.86
Adenocarcinoma	234 (49 %)	33 (54 %)	
NET	197 (42 %)	24 (39 %)	
Other	27 (6 %)	*	
Tumor location			0.53
Tail	359 (76 %)	44 (72 %)	
Body	115 (24 %)	17 (28 %)	
Tumor size (cm)	3.6 ± 2	3.8 ± 2.2	0.50
Stage			0.07
I	185 (39 %)	26 (43 %)	
II	250 (53 %)	27 (44 %)	
III	*	0	
IV	21 (4 %)	*	
Conversion to open	113 (23 %)	*	0.14
Complete surgical resection	44 (9 %)	*	0.64
Number of LNs (mean ± SD)	12 ± 9	12 + 10	0.45
LOS (mean ± SD, days)	6 ± 4	8 + 10	0.54
Unplanned 30-day readmission	51 (11 %)	*	0.66
30-day mortality	*	0	1

Values are presented as percentages of given sample size. Percentages were rounded and may not add to 100 due to missing values. Patient age in decades

NCDB National Cancer Data Base, *SD* standard deviation, *NET* neuroendocrine tumor, *NOS* not otherwise specified, *LNs* lymph nodes, *SD* standard deviation, *LOS* length of stay, *OR* odds ratio, *CI* confidence interval

* Suppressed due to small cell size, per NCDB policy

College of Surgeons' National Surgical Quality Improvement Project (ACS-NSQIP) datasets indicated that incidence of MIDP may be underestimated in HCUP-NIS [13].

To date, there are no randomized clinical trials examining outcomes from minimally invasive compared to open surgery; however, retrospective data exist from high-volume institutions. Magge et al. analyzed data from 64 patients who had minimally invasive and ODP for adenocarcinoma. Minimally invasive surgery was associated with less blood loss (290 vs. 570 ml, $p = 0.006$) and shorter length of stay (6 vs. 8 days, $p = 0.03$), but similar incidence of postoperative complications. Rates of postoperative negative margins (86 vs. 88 %) and overall survival were also equivalent [11]. Kooby et al. compared data from 142 patients who underwent MIDP to 200 patients who had open distal pancreatic surgery for benign and malignant pancreatic disease at eight institutions. After matching for patient age, ASA scores, tumor size, and diagnosis, the minimally invasive group had significantly fewer complications (40 vs. 57 %, $p < 0.01$) and shorter length of stay (6 vs. 9 days, $p < 0.01$), with no difference in positive margin rates (8 vs. 7 %, $p = 80$) [6]. In a recent meta-analysis comparing minimally invasive versus ODP from 18 studies, minimally invasive surgery was associated with significantly fewer complications and a shorter length of hospital stay. The likelihood of margin positivity was not different between the two groups (OR 0.63, CI 0.21–1.89, $p = 0.41$) [10]. Our nationally representative results are consistent with these findings.

Prior population-level data have focused on perioperative outcomes from MIDP, but they did not address the role of minimally invasive surgery in achieving complete tumor resection. In a large study of 8957 distal pancreatectomies from HCUP-NIS (1998–2009), MIDP was associated with lower rates of complications, as well as shorter length of hospital stay. There were no differences in rates of in-hospital mortality or in total hospital charges [12]. In another report that included data from ACS-NSQIP and HCUP-NIS, Rosales-Velderrain et al. compared perioperative outcomes from minimally invasive versus ODP for benign and malignant conditions. In both datasets, minimally invasive surgery was associated with fewer overall complications, shorter length of stay, and reduced hospital cost [13]. Of note, these population-based studies are limited by lack of data on tumor-specific characteristics; these factors were not accounted for in their analyses. In our study, adjustment was made for tumor characteristics such as size, histologic diagnosis, AJCC stage, and location within the pancreas.

While our findings suggest that MIDP is associated with similar short-term oncologic outcomes and shorter length of stay compared to open surgery for pancreatic adenocarcinoma, we believe that appropriate patient selection is essential. As shown, patients who had minimally invasive surgery had favorable tumor characteristics, including smaller size and a location in the tail of the pancreas. Given the retrospective nature of this study, we believe that interpretation of these favorable outcomes from minimally invasive surgery should be taken in the context of possible selection bias; as such, minimally invasive technique may be beneficial in a select group of pancreatic cancer patients.

In our study, there were 12 patients who had distant metastases at the time of diagnosis who underwent minimally invasive surgery. All patients with distant metastases had surgery at low-volume centers (<10 cases/2 years). This is particularly concerning, as the presence of distant metastases in the setting of a diagnosis of pancreatic adenocarcinoma generally is treated as a contra-indication for surgical resection. Completeness of tumor resection and the number of lymph nodes removed were superior at high-volume institutions, as shown in previous studies [18]. These findings emphasize the important association of hospital procedural volume with improved patient selection and outcomes.

The vast majority of patients who had MIDP were reported from low-volume hospitals that performed <10 cases over the 2 years. This is concerning, as accumulating evidence demonstrates significantly increased morbidity and mortality from pancreatectomy when the procedure is performed at low-volume hospitals [14, 19]. Efforts should be made to disseminate information regarding this observation to patients and referring physicians, given that patients with pancreatic cancer requiring minimally invasive or ODP may benefit from referral to high-volume hospitals.

After accounting for clinical and disease characteristics, lack of insurance was associated with surgical approach. This concerning finding highlights the existence of socioeconomic disparities in surgical treatment of pancreatic cancer. Possible reasons for more utilization of minimally invasive surgery among insured patients include their better access to medical information and higher volume providers. It also is possible that there may be a belief that laparoscopic surgery has higher operative costs than open surgery, and therefore uninsured patients would incur more expenses; however, it has been shown that the pre- and intra-operative costs are equivalent for open versus laparoscopic approaches, with lower total hospital costs for the patients undergoing laparoscopic distal pancreatectomy [20].

There are limitations to our study, including the potential for coding errors; however, the NCDB uses standardized abstraction and coding methods. Data on concurrent use of splenectomy, development of pancreatic fistula, and other procedure-specific complications were not reported in the dataset. Development of pancreatic fistula is particularly important when comparing outcomes of different pancreatectomy techniques. We have tried to provide a proxy for this by analyzing rates of unplanned readmissions and length of stay. Survival data were not reported for this NCDB cohort. Although we adjusted for all possible confounders available, there may be unmeasured selection bias given the retrospective nature of the study.

The strength of the current study lies in its nationally representative nature, giving a more accurate estimate of the use of MIDP for cancer in the United States. It also addresses for the first time at a population-level completeness of resection, which bears critical prognostic significance in pancreatic adenocarcinoma [21]. Overall, it is reassuring that MIDP is associated with equivalent rates of complete resection compared to open surgery. While high-volume hospitals appear to have higher rates of complete tumor resection, the majority of hospitals performing minimally invasive distal pancreatectomies were in the low-volume category, where resection margins were more often positive. Appropriate patient selection for a minimally invasive approach to distal pancreatectomy is essential, and patient access to hospitals affording the best outcomes should be optimized. Studies of longer term patient outcomes from MIDP are necessary.

Compliance with Ethical Standards

Conflict of interest The authors report no conflicts of interest. The data used in the study are derived from a de-identified NCDB file. The American College of Surgeons and the Commission on Cancer have not verified and are not responsible for the analytic or statistical methodology employed, or the conclusions drawn from these data by the investigators.

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