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National disparities in minimally invasive surgery for pancreatic tumors

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Abstract

Background For patients with pancreatic tumors, several disparities have been shown to impact access to care, including surgery, and subsequently adversely affect long-term oncologic outcomes. The aim of this study was to investigate national disparities in minimally invasive surgery (MIS) across different demographics for pancreatic tumors.

Methods We utilized the American College of Surgeons (ACS) National Cancer Data Base (NCDB) to identify patients with pancreatic tumors from 2010 to 2011 who had undergone surgery through either an open or MIS approach. Multivariable analysis was performed to investigate differences in patient characteristics in relation to surgical approach and conversion to open.

Results A total of 2809 patients were identified. The initial surgical approach included 86.5 % open (2430) and 13.5 % MIS (87.6 % were laparoscopic, and 12.4 % were robotic). Tumor histology was significantly associated with MIS, whereby patients with neuroendocrine tumors were more than twice as likely to have an MIS approach compared to adenocarcinoma. Tumor location within the pancreas was also associated with MIS, with tumors in the tail being three times more likely to be removed through MIS compared to tumors in the head. For patients with disease in the body or tail of the pancreas, ethnicity was independently associated with MIS whereby patients of Hispanic origin were less likely to have MIS. The conversion rate to open was 27.7 %, and geographic location was associated with conversion rates.

Conclusions MIS procedures comprise approximately 13.5 % of surgical procedures for pancreatic tumors. In addition to tumor histology, differences in surgical approach were identified with respect to ethnicity for patients with tumors in the body/tail of the pancreas.

Keywords Pancreatic tumors · Laparoscopic and robotic surgery · Disparities

Disclaimers The American College of Surgeons Committee on Cancer provided the Participant User File from the National Cancer Data Base, but has not reviewed or validated the results or conclusions of our study.

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Pancreatic tumors include adenocarcinoma, neuroendocrine tumors and cystic neoplasms. Pancreatic adenocarcinoma is the fourth most common cause of cancer-related mortality in the USA [1]. The median overall survival (OS) is about 20 months with a 5-year OS of approximately 7.2 % [2–4]. Pancreatic neuroendocrine tumors (PNETs) and cystic neoplasms, including mucinous cystic neoplasm (MCNs) and intraductal papillary mucinous neoplasms (IPMNs), have a lower prevalence than adenocarcinoma, with estimates that these entities each comprise 1–2 % of all pancreatic tumors [5–7]. Compared to pancreatic adenocarcinoma, prognosis of these other pancreatic tumors are generally much better.

For patients with resectable pancreatic tumors, the surgical approach to resection has expanded in the last decade to include minimally invasive surgery (MIS) for disease in the head, body or tail of the pancreas [8–11]. Whereas open surgery has long been the standard for either pancreaticoduodenectomy or distal pancreatectomy, both laparoscopic surgery and robotic-assisted surgery (RAS) are performed for these anatomic resections. Surgery, regardless of approach, is often used in combination with other treatment modalities such as chemotherapy, to achieve the best long-term outcomes. As outlined by the National Comprehensive Cancer Network (NCCN) guidelines, a multidisciplinary approach to treatment is recommended in the care of patients with pancreatic tumors [12].

Optimizing outcomes for these diseases often requires access to the different treatment modalities, including surgery. However, many studies have identified that a multitude of disparities exist in the care for patients with pancreatic tumors, and that these disparities have significant impact on oncologic outcomes [13, 14]. Several patient demographics have been shown to have disparate results on pancreatic tumor outcomes, particularly in the setting of adenocarcinoma as this is a more common entity. These include age [15, 16], race [17–24], type of insurance [20], socioeconomic status [13, 25–27] and geographic location [28, 29]. These disparities have been associated with decreased recommendations for surgery with resectable disease, decreased rates of surgery even when recommended and poorer OS survival in patients who are older, minorities, uninsured, less affluent or less educated, or live in lower-income communities within the USA. With the increasing application of MIS to pancreatic tumors, it is of unique interest to determine whether similar disparities exist with regard to surgical approach for patients who are offered resection. Thus, the objectives of this study were to characterize factors associated with MIS for patients with pancreatic tumors and investigate national disparities in the MIS approach.

Methods

Patients

The National Cancer Data Base (NCDB) is jointly maintained by the American College of Surgeons Commission on Cancer (CoC) and the American Cancer Society (ACS). The NCDB captures approximately 70 % of the country's tumors cases through its participating hospitals. The Participant User File (PUF) for pancreas was used. This study was deemed exempt from institutional review.

Since 2010, surgical approach has been recorded and includes the open, laparoscopic, laparoscopic converted to open, robotic and robotic converted to open approaches. For the purposes of this study, patients with pancreatic tumors treated with surgery from 2010 to 2011 were identified. When this study was conducted, data from the NCDB were available only until 2011.

Figure 1 illustrates the sequential criteria for patient selection. Inclusion criteria included patients with a history of only one malignancy who did not receive any neoadjuvant chemotherapy or radiation treatment. Patients who received adjuvant therapy were included. Patients with benign neuroendocrine tumors or cystic tumors were excluded. Patients with clinical stage 1–3 were included. Clinical stage was used as opposed to pathologic stage as the decision to perform surgical resection would have been based on clinical stage and not on pathologic stage. Patients with clinical stage IV disease were excluded. In contrast, patients with pathologic stage IV disease were still included, as this staging would have been discovered during or after surgery, which occurred after the decision had already been made to offer resection through either an open or MIS approach. Pathologic staging for adenocarcinoma and PNETs during the study time period was based on the 7th edition of the American Joint Committee on Cancer, 2009 [30].

Although chemoradiation plays a role in the treatment of pancreatic cancer, studies have characterized a diverse set of disparities regarding access to these treatments in the neoadjuvant setting [20, 23, 26]. Therefore, to focus this analysis on surgical approach and its associated disparities, patients who received any neoadjuvant chemotherapy or radiation were excluded. In contrast, the decision to receive adjuvant therapy would have been made following the decision for surgery and the surgical approach. Therefore, patients treated with adjuvant therapy were included. Lastly, patients with missing data were excluded.

Patients offered MIS but then converted to open were analyzed in their respective MIS group, including laparoscopic and robotic, since the primary goal was to determine disparities in access to MIS. Due to the relatively lower numbers of MIS procedures offered for pancreatic tumors as compared to open surgery, the laparoscopic and RAS approaches were combined into one group, designated as MIS. A separate multivariable analysis was performed to identify factors associated with conversion to open. Surgical procedures include local excision (enucleation), partial or distal pancreatectomy, pancreaticoduodenectomy and total pancreatectomy. The NCDB records the definitive procedure performed at a specific site, which includes the head, body or tail of the pancreas. However, the type of surgical procedure as it relates to disparities was excluded from the analysis because the decision to convert a minimally invasive procedure to an open procedure could have influenced the final surgery type that was ultimately performed. For example, a planned MIS local excision or enucleation of a

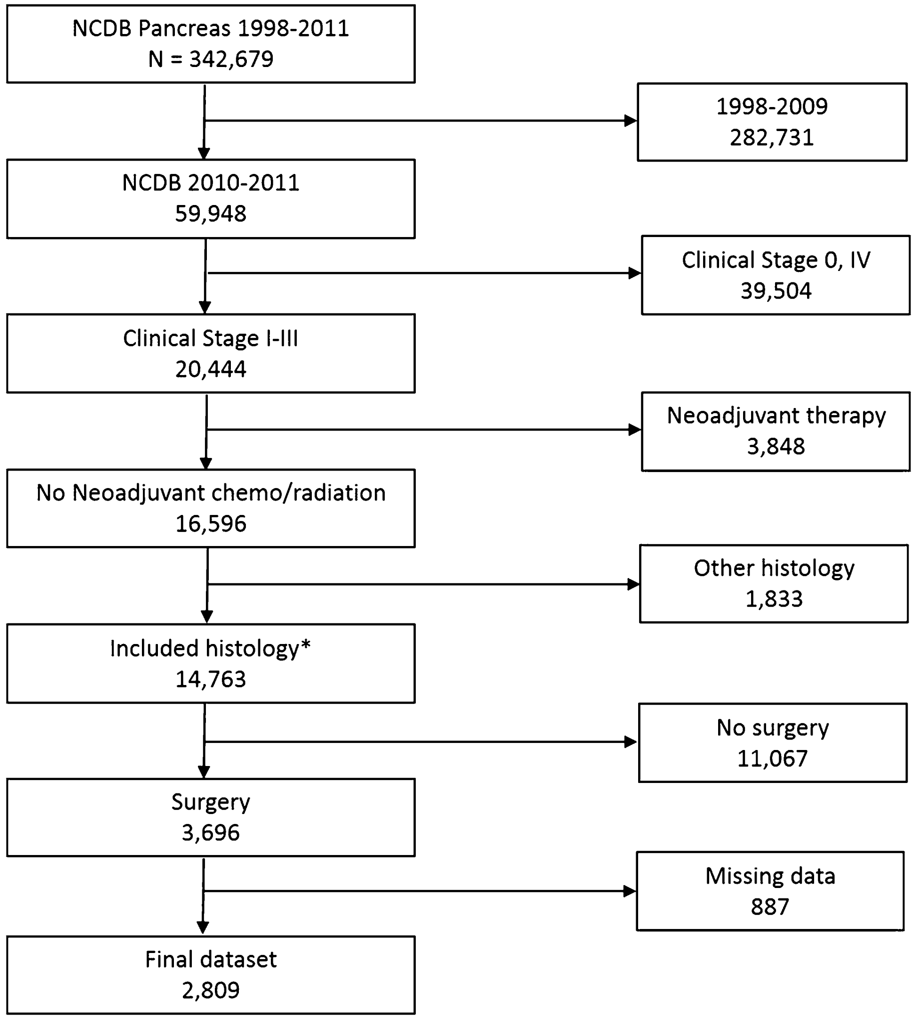

Fig. 1 Flow diagram showing the sequential inclusion and exclusion criteria for patients used in the analysis

neuroendocrine tumor may be altered to a distal pancreatectomy after conversion to open.

For adenocarcinoma histology, the following International Classification of Diseases for Oncology, 3rd edition (ICD-O-3) codes were used: 8140–8148, 8200, 8260–8263 and 8480–8496. For neuroendocrine histology, the following ICD-O-3 codes were used: 8150–8155 and 8240–8253. Lastly, for cystic neoplasms of the pancreas, the following ICD-O-3 codes were used: 8440–8442, 8450–8453, 8460–8461, 8470–8473 and 8480–8496.

Other pathologic factors included tumor size, grade, clinical stage and pathological stage. Demographic factors included patient age, gender, race, income, education, insurance status, facility type, distance from treating facility, geographic setting (rural, urban or metropolitan) and geographic location. The NCDB divides the USA into nine geographic regions, including New England (CT, MA, ME, NH, RI, VT) Middle Atlantic (NJ, NY, PA), South Atlantic (DC, DE, FL, GA, MD, NC, SC, VA, WV), East North Central (IL, IN, MI, OH, WI), East South Central (AL, KY, MS, TN), West North Central (IA, KS, MN, MO, ND, NE, SD), West South Central (AR, LA, OK, TX), Mountain (AZ, CO, ID, MT, NM, NV, UT, WY) and Pacific (AK, CA, HI, OR, WA). The NCDB records the Charlson-Deyo score as an estimate of patient comorbidity.

Univariate and multivariable analyses were performed for the cohort as a whole in order to identify independent predictors of surgical approach. Recognizing the extent of technical differences between pancreaticoduodenectomy and distal pancreatectomy, analysis of disparities was performed within subsets based on site of disease, namely head versus body/tail. Recognizing that insurance is related to age such that patients over 65 qualify for Medicare, we stratified insurance type by age <65 and age ≥ 65 in a separate analysis to account for this factor.

Statistical analysis

Patient characteristics are reported using the mean, median and standard deviation for continuous variables, and using frequencies and relative frequencies for categorical variables. Comparisons were made between procedures using the Kruskal–Wallis and Chi-square tests for continuous and categorical variables, respectively. Multinomial general linear models were used to identify a set of patient characteristics that are significantly associated with a given surgical approach. The variables included in the model were obtained using the backward selection method ($\alpha = 0.05$). Baseline category odds ratios (ORs) were obtained from the fitted model and represent the odds of having a MIS procedure as compared to an open surgery for a change in the given patient characteristic. These models determined which demographic and oncologic variables were independently associated with each of type of surgical approach. All analyses were conducted in SAS version 9.4 (Cary, NC) at a significance level of 0.05.

Results

A total of 342,679 patients are included in the NCDB pancreas PUF, which at the time of this study spanned from 1998 to 2011. Figure 1 illustrates the inclusion and exclusion criteria. A total of 2809 patients with pancreatic tumors who had undergone surgery were identified between 2010 and 2011. The majority of patients (86.5 %) had open surgical procedures compared to 13.5 % who underwent MIS. Of patients who had MIS, 87.6 % (332/379) were performed laparoscopically and 12.4 % (47/379) were performed with robotic assistance. There was a trend toward increased MIS procedures overall from 2010 to 2011, specifically for surgery to the head of the pancreas (Supplemental Table 1).

Patient characteristics of the entire cohort are shown in Table 1. The majority of patients were either clinical stage I or II for each surgical approach. Table 2 shows the multivariable analysis of both the demographic variables and oncologic characteristics as predictors of surgical approach for the entire cohort. Compared to open surgery, primary site of tumor and tumor histology were the only oncologic factors associated with increased odds ratios (ORs) for MIS, whereby patients with disease of the body/tail of the pancreas and neuroendocrine histology were more likely to undergo MIS. The remaining pathologic variables were not significantly predictive factors for MIS as compared to open surgery. Regarding patient demographic factors, age and treatment facility type were statistically associated with surgical approach.

Recognizing that the primary site of tumor can have profound implications on surgical approach, taken together with the finding that primary site was found to be independently associated with surgical approach, subgroup multivariable analyses were performed for patients who had tumors of the head versus the body/tail. Table 3 shows the multivariable analysis of these characteristics on the likelihood of MIS for patients with tumors of the head. Similarly, Table 4 shows the corresponding data for patients with tumors of the body/tail. Altogether, these analyses showed that ethnicity was the only demographic factor associated with MIS for the body/tail. Patients of Hispanic origin were less likely to undergo MIS of the body/tail (Hispanic vs. non-Hispanic OR 0.24, 95 % CI 0.07–0.79, $P = 0.019$).

Recognizing that patients who qualify for Medicare must be age 65 years or older, we analyzed insurance status for patients in this older age group (Supplemental Table 2). Patients aged 65 and older comprised 1997 patients (71.1 % of the entire group), with the majority having Medicare. In this subgroup of patients, insurance status was not associated with surgical approach, even when stratified by primary site of tumor.

Supplemental Table 3 shows factors associated with conversion to open. Of the 524 MIS cases, 27.7 % (145) underwent conversion to open. On multivariable analysis shown in Supplemental Table 4, only geographic location was associated with conversion.

Discussion

Disparities in access to care have been extensively studied in patients with pancreatic tumors. Access to and completion of surgery are of particular importance in the current era of expanding MIS for pancreatic tumors where surgical intervention may offer potential cure for patients with resectable disease in the setting of limited systemic therapy options. The MIS approach has been increasingly performed for pancreatic tumors [9, 31, 32]. While laparoscopic surgery for distal pancreatectomies was among the initial applications of MIS for the pancreas, its use for pancreaticoduodenectomies is being increasingly developed across the USA and abroad [33, 34].

Studies of both laparoscopic surgery and RAS in pancreatic surgery have established the oncologic equivalency to open surgery and proposed additional short-term benefits. Particularly in the setting of distal pancreatectomies for adenocarcinoma, the short-term outcomes of MIS have been comparable to open surgery with regard to safety and efficacy [31, 35]. Results from high-volume centers performing RAS for pancreatic adenocarcinoma have also shown similar results as compared to open or laparoscopic

Table 1 Characteristics of patients with pancreatic tumors who underwent open versus minimally invasive (laparoscopic and robotic) procedures

	Open	MIS	Overall	*P* value
Overall				
N	2430 (86.5 %)	379 (13.5 %)	2809 (100 %)	
Age				
Mean/std[a]	64.92/12.44	64.79/12.42	64.90/12.43	0.82
Median/min/max	66.00/19.00/90.00	66.00/26.00/90.00	66.00/19.00/90.00	
Gender				
Male	1220 (50.2 %)	185 (48.8 %)	1405 (50.0 %)	0.61
Female	1210 (49.8 %)	194 (51.2 %)	1404 (50.0 %)	
Race				
White	2039 (84.7 %)	326 (86.7 %)	2365 (85.0 %)	0.76
Black	270 (11.2 %)	37 (9.8 %)	307 (11.0 %)	
Asian	61 (2.5 %)	9 (2.4 %)	70 (2.5 %)	
Other	36 (1.5 %)	4 (1.1 %)	40 (1.4 %)	
Ethnicity				
Non-Hispanic	2211 (94.5 %)	348 (95.1 %)	2559 (94.6 %)	0.66
Hispanic	128 (5.5 %)	18 (4.9 %)	146 (5.4 %)	
Insurance				
Private	982 (40.8 %)	157 (42.1 %)	1139 (41.0 %)	0.75
Medicaid	119 (4.9 %)	17 (4.6 %)	136 (4.9 %)	
Medicare	1210 (50.3 %)	184 (49.3 %)	1394 (50.1 %)	
Other	28 (1.2 %)	2 (0.5 %)	30 (1.1 %)	
Not insured	68 (2.8 %)	13 (3.5 %)	81 (2.9 %)	
Income[b]				
<$30,000	333 (14.7 %)	47 (13.4 %)	380 (14.6 %)	0.93
$30,000–$34,999	410 (18.1 %)	64 (18.2 %)	474 (18.2 %)	
$35,000–$45,999	608 (26.9 %)	97 (27.6 %)	705 (27.0 %)	
≥$46,000	909 (40.2 %)	143 (40.7 %)	1052 (40.3 %)	
Education[c]				
≥29 %	408 (18.1 %)	54 (15.4 %)	462 (17.7 %)	0.37
20.0–28.9 %	510 (22.6 %)	89 (25.4 %)	599 (22.9 %)	
14.0–19.9 %	502 (22.2 %)	85 (24.2 %)	587 (22.5 %)	
<14.0 %	840 (37.2 %)	123 (35.0 %)	963 (36.9 %)	
Facility type				
Community cancer program (CCP)	46 (1.9 %)	4 (1.1 %)	50 (1.8 %)	0.13
Comprehensive CCP	750 (30.9 %)	102 (26.9 %)	852 (30.4 %)	
Academic/research program	1630 (67.2 %)	273 (72.0 %)	1903 (67.8 %)	
Facility location				
New England	81 (3.3 %)	17 (4.5 %)	98 (3.5 %)	0.002
Middle Atlantic	390 (16.0 %)	82 (21.6 %)	472 (16.8 %)	
South Atlantic	603 (24.8 %)	95 (25.1 %)	698 (24.8 %)	
East North Central	391 (16.1 %)	64 (16.9 %)	455 (16.2 %)	
East South Central	190 (7.8 %)	27 (7.1 %)	217 (7.7 %)	
West North Central	178 (7.3 %)	33 (8.7 %)	211 (7.5 %)	
West South Central	208 (8.6 %)	27 (7.1 %)	235 (8.4 %)	
Mountain	137 (5.6 %)	5 (1.3 %)	142 (5.1 %)	
Pacific	252 (10.4 %)	29 (7.7 %)	281 (10.0 %)	

Table 1 continued

	Open	MIS	Overall	*P* value
Urban/rural				
Metro	1829 (81.1 %)	277 (78.2 %)	2106 (80.7 %)	0.24
Urban	393 (17.4 %)	68 (19.2 %)	461 (17.7 %)	
Rural	34 (1.5 %)	9 (2.5 %)	43 (1.6 %)	
Distance				
Mean/std	72.97/193.15	74.15/173.40	73.13/190.55	0.36
Median/min/max	22.30/0.20/2661.3	23.70/0.40/1535.0	22.50/0.20/2661.3	
Charlson-Deyo[d]				
0	1579 (65.0 %)	248 (65.4 %)	1827 (65.0 %)	0.98
1	667 (27.4 %)	103 (27.2 %)	770 (27.4 %)	
2	184 (7.6 %)	28 (7.4 %)	212 (7.5 %)	
Primary site				
Head	1819 (74.9 %)	189 (49.9 %)	2008 (71.5 %)	<.001
Body	263 (10.8 %)	54 (14.2 %)	317 (11.3 %)	
Tail	348 (14.3 %)	136 (35.9 %)	484 (17.2 %)	
Grade				
I	545 (25.7 %)	137 (40.2 %)	682 (27.7 %)	<.001
II	935 (44.1 %)	129 (37.8 %)	1064 (43.2 %)	
III	616 (29.1 %)	73 (21.4 %)	689 (28.0 %)	
IV	24 (1.1 %)	2 (0.6 %)	26 (1.1 %)	
Histology				
Adenocarcinoma	1820 (74.9 %)	212 (55.9 %)	2032 (72.3 %)	<.001
PNET[e]	500 (20.6 %)	151 (39.8 %)	651 (23.2 %)	
Cystic	110 (4.5 %)	16 (4.2 %)	126 (4.5 %)	
Tumor size (cm)				
<1	80 (3.4 %)	17 (4.6 %)	97 (3.5 %)	0.003
1–2	291 (12.2 %)	72 (19.4 %)	363 (13.2 %)	
2–3	636 (26.7 %)	99 (26.6 %)	735 (26.7 %)	
3–4	636 (26.7 %)	88 (23.7 %)	724 (26.3 %)	
4–5	358 (15.0 %)	51 (13.7 %)	409 (14.9 %)	
>5	378 (15.9 %)	45 (12.1 %)	423 (15.4 %)	
Tumor size (mm)				
Mean/std	34.57/23.51	30.60/16.32	34.03/22.71	<.001
Median/min/max	31.00/0.50/700.0	28.50/0.50/150.0	30.00/0.50/700.0	
Clinical stage				
Stage 1	1062 (43.7 %)	215 (56.7 %)	1277 (45.5 %)	<.001
Stage 2	1237 (50.9 %)	150 (39.6 %)	1387 (49.4 %)	
Stage 3	131 (5.4 %)	14 (3.7 %)	145 (5.2 %)	
Path stage				
Stage 1	501 (20.6 %)	128 (33.8 %)	629 (22.4 %)	<.001
Stage 2	1520 (62.6 %)	206 (54.4 %)	1726 (61.4 %)	
Stage 3	67 (2.8 %)	5 (1.3 %)	72 (2.6 %)	
Stage 4	43 (1.8 %)	2 (0.5 %)	45 (1.6 %)	

Table 1 continued

	Open	MIS	Overall	*P* value
Approach (MIS)				
Robotic		47 (12.4 %)	47 (1.7 %)	N/A
Laparoscopic		332 (87.6 %)	332 (11.8 %)	

[a] Standard deviation

[b] Income as reported by the NCDB is the median household income for the area of residence of a given patient based on zip code derived from the 2000 US Census

[c] Education as reported by the NCDB is the percentage of adults in the area of residence of a given patient (based on zip code derived from the 2000 US Census) who did not graduate from high school

[d] Charlson-Deyo comorbidity score is an estimate of comorbid conditions based on ICD-9 diagnosis codes. A score of 0 indicates no comorbidities. Point values are assigned to comorbid conditions based on severity. The NCDB truncates possible scores to 0, 1 and 2 due to the small proportion of cases exceeding a score of 2

[e] Pancreatic neuroendocrine tumor

surgery, mainly for distal pancreatectomies but more recently with the more technically involved pancreaticoduodenectomy as well [33, 34, 36–38]. These studies suggest that MIS may provide additional benefits over open surgery, including less intraoperative estimated blood loss, improved postoperative pain and shorter postoperative hospital admission length of stay, albeit with substantially increased monetary costs [39, 40]. Similar data supporting benefits of MIS exist for PNETs, albeit with much smaller numbers of patients due to the relatively lower incidence of disease [10, 41, 42]. As the costs associated with RAS are better addressed, disparities in surgical approach for pancreatic tumors may become increasingly relevant.

In this study using a large, comprehensive national database, disparities specific to MIS for pancreatic tumors were identified. Tumor histology was significantly associated with MIS, whereby patients with neuroendocrine tumors were twice as likely to undergo MIS compared to adenocarcinoma. A likely reason for this observation may be that neuroendocrine tumors tend to be less locally invasive than adenocarcinoma, allowing a more technically feasible MIS resection.

Treatment facility type (academic center, comprehensive cancer center and community center) was identified as being independently associated with MIS. One may hypothesize that large, tertiary academic cancer centers specializing in MIS have more experienced surgeons with MIS techniques, which could account for these disparities. The intraoperative equipment and perioperative treatment facilities and postoperative pathways may also differ among the various treatment facility types. These differences may also account for the varying levels of conversion to open across different geographic locations. These factors, however, are not captured by the NCDB and therefore represent an inherent limitation to this study.

Ethnic disparities were present for patients with body/tail pancreatic tumors, whereby patients of Hispanic origin were less likely to undergo MIS. Although one might conclude that this finding could be related to geographic location and the available treatment facilities in locations with higher Hispanic populations, ethnicity remained statistically significant as an independently associated factor with surgical approach on multivariable analysis. Thus, other reasons explaining this disparity likely exist. These may include the experience of the treating surgeon in MIS techniques and the attitudes of the surgeon and/or patient to surgical approach, which are factors unable to be captured by the database. Such disparities reflect differences in access to care that may account for Hispanic patients being offered less MIS approaches for pancreatic tumors. The majority of studies investigating racial disparities in pancreatic surgery and tumors outcomes have identified African-Americans as a minority population with poorer access to treatment, less often receiving recommendations for treatment including surgery and chemotherapy and having poorer outcomes compared with Caucasians [17, 20, 22, 24]. Interestingly, in this study utilizing the NCDB, there were no disparities with respect to surgical approach found between African-American patients and Caucasian patients regardless of the site of primary tumor.

Of note, previous studies investigating disparities in pancreatic cancer care using the NCDB have been performed, though the focus has not been on MIS. One study published in the mid-1990s identified race and treatment at facility type as disparate variables associated with differences in care, whereby African-American patients, patients with lower socioeconomic status and patients treated at smaller non-teaching hospitals presented with more advanced disease and were less likely to undergo curative resection [43]. A more recent study by Bilimoria et al. [44], using NCDB data from 1995 to 2004, reported a significant underuse of surgery in potentially curative cases, whereby patients who were older than age 65, African-American, poorer, less educated and had Medicare or Medicaid were less likely to have surgery.

Table 2 Multivariable analysis of predictors of surgical approach

Variable	Level	OR (95 % CI)	*P* value
Age	1-year increase	1.014 (1.000, 1.028)	0.047
Gender	Female versus male	1.132 (0.870, 1.473)	0.36
Race	Black versus White	0.912 (0.592, 1.405)	0.61
	Asian versus White	1.371 (0.612, 3.071)	
	Other versus White	0.410 (0.072, 2.354)	
Ethnicity	Hispanic versus non-Hispanic	0.591 (0.292, 1.195)	0.14
Insurance	Medicaid versus private	1.039 (0.549, 1.964)	0.58
	Medicare versus private	0.859 (0.606, 1.217)	
	Other versus private	0.390 (0.067, 2.259)	
	Not insured versus private	1.395 (0.649, 3.000)	
Income	\$30–\$34,999 versus <\$30,000	1.122 (0.692, 1.820)	0.79
	\$35–\$45,999 versus <\$30,000	0.911 (0.550, 1.508)	
	≥\$46,000 versus <\$30,000	1.022 (0.582, 1.795)	
Education	20–28.9 versus ≥29 %	1.333 (0.858, 2.070)	0.55
	14–19.9 versus ≥29 %	1.242 (0.744, 2.071)	
	<14 versus ≥29 %	1.104 (0.641, 1.901)	
Facility type	Comp CCP versus CCP	1.819 (0.557, 5.945)	0.046
	Academic/research versus CCP	2.509 (0.773, 8.146)	
Charlson-Deyo	1 versus 0	1.011 (0.754, 1.356)	0.90
	2 versus 0	1.125 (0.673, 1.881)	
Primary site	Body versus head	1.471 (0.968, 2.235)	<.001
	Tail versus head	3.223 (2.297, 4.523)	
Facility location	Middle Atlantic versus New England	0.920 (0.464, 1.823)	0.09
	South Atlantic versus New England	0.767 (0.389, 1.511)	
	East North Central versus New England	0.736 (0.368, 1.470)	
	East South Central versus New England	0.640 (0.287, 1.429)	
	West North Central versus New England	0.808 (0.372, 1.753)	
	West South Central versus New England	0.457 (0.200, 1.043)	
	Mountain versus New England	0.136 (0.033, 0.558)	
	Pacific versus New England	0.640 (0.293, 1.396)	
Grade	II versus I	1.320 (0.837, 2.082)	0.62
	III versus I	1.162 (0.702, 1.924)	
	IV versus I	0.956 (0.235, 3.894)	
Histology	PNET versus adenocarcinoma	2.060 (1.278, 3.318)	0.011
	Cystic versus adenocarcinoma	1.465 (0.765, 2.804)	
Tumor size (cm)	1–2 versus <1	1.694 (0.762, 3.765)	0.07
	2–3 versus <1	1.612 (0.726, 3.580)	
	3–4 versus <1	1.440 (0.638, 3.253)	
	4–5 versus <1	1.484 (0.640, 3.442)	
	>5 versus <1	0.836 (0.355, 1.965)	
Clinical stage	Stage 2 versus stage 1	0.900 (0.660, 1.227)	0.60
	Stage 3 versus stage 1	1.258 (0.597, 2.651)	
Path stage	Stage 2 versus stage 1	0.867 (0.603, 1.248)	0.33
	Stage 3 versus stage 1	0.303 (0.078, 1.185)	
	Stage 4 versus stage 1	0.421 (0.110, 1.616)	

Table 3 Multivariable analysis of surgical approach for patients with tumors of the head of the pancreas

Variable	Level	OR (95 % CI)	*P* value
Age	1-year increase	1.008 (0.988, 1.028)	0.43
Gender	Female versus male	1.138 (0.808, 1.603)	0.46
Race	Black versus White	1.037 (0.585, 1.839)	0.38
	Asian versus White	2.064 (0.771, 5.528)	
	Other versus White	0.245 (0.015, 3.986)	
Ethnicity	Hispanic versus non-Hispanic	1.222 (0.527, 2.831)	0.64
Insurance	Medicaid versus private	0.675 (0.251, 1.817)	0.24
	Medicare versus private	0.983 (0.619, 1.560)	
	Other versus private	0.962 (0.171, 5.399)	
	Not insured versus private	2.304 (1.033, 5.137)	
Income	\$30–\$34,999 versus <\$30,000	1.225 (0.686, 2.188)	0.31
	\$35–\$45,999 versus <\$30,000	0.757 (0.399, 1.436)	
	≥\$46,000 versus <\$30,000	0.755 (0.367, 1.555)	
Education	20–28.9 versus ≥29 %	1.073 (0.611, 1.885)	0.67
	14–19.9 versus ≥29 %	1.439 (0.751, 2.757)	
	<14 versus ≥29 %	1.241 (0.612, 2.518)	
Facility type	Comp CCP versus CCP	1.073 (0.189, 6.104)	0.54
	Academic/research versus CCP	1.333 (0.236, 7.519)	
Facility location	Middle Atlantic versus New England	0.984 (0.371, 2.612)	0.31
	South Atlantic versus New England	0.755 (0.289, 1.973)	
	East North Central versus New England	0.853 (0.320, 2.272)	
	East South Central versus New England	0.825 (0.279, 2.439)	
	West North Central versus New England	1.099 (0.382, 3.164)	
	West South Central versus New England	0.357 (0.109, 1.172)	
	Mountain versus New England	0.279 (0.059, 1.322)	
	Pacific versus New England	0.707 (0.240, 2.086)	
Charlson-Deyo	1 versus 0	1.441 (0.995, 2.086)	0.15
	2 versus 0	1.225 (0.640, 2.344)	
Grade	II versus I	1.023 (0.559, 1.873)	0.99
	III versus I	0.982 (0.519, 1.860)	
	IV versus I	0.944 (0.216, 4.120)	
Histology	PNET versus adenocarcinoma	1.559 (0.787, 3.089)	0.24
	Cystic versus adenocarcinoma	1.675 (0.776, 3.615)	
Tumor size (cm)	1–2 versus <1	1.300 (0.308, 5.492)	0.55
	2–3 versus <1	1.375 (0.336, 5.627)	
	3–4 versus <1	1.417 (0.346, 5.811)	
	4–5 versus <1	1.753 (0.416, 7.387)	
	>5 versus <1	0.848 (0.188, 3.823)	
Clinical stage	Stage 2 versus stage 1	0.934 (0.637, 1.369)	0.30
	Stage 3 versus stage 1	1.768 (0.780, 4.010)	
Path stage	Stage 2 versus stage 1	0.849 (0.507, 1.422)	0.62
	Stage 3 versus stage 1	0.503 (0.122, 2.073)	
	Stage 4 versus stage 1	0.189 (0.012, 3.009)	

There are important limitations to our study. By excluding patients who received neoadjuvant chemotherapy or radiation, there are fewer patients in the analysis, and disparities related to systemic treatment are not evaluated. During the study time period, the penetration of MIS for distal pancreatectomy for tumors of the body or tail was

Table 4 Multivariable analysis of surgical approach for patients with tumors of the body or tail of the pancreas

Variable	Level	OR (95 % CI)	*P* value
Age	1-year increase	1.017 (0.997, 1.037)	0.10
Gender	Female versus male	0.982 (0.645, 1.493)	0.93
Race	Black versus White	0.747 (0.384, 1.453)	0.85
	Asian versus White	0.992 (0.252, 3.912)	
	Other versus White	0.713 (0.079, 6.401)	
Ethnicity	Hispanic versus non-Hispanic	0.235 (0.070, 0.786)	0.019
Insurance	Medicaid versus private	1.522 (0.627, 3.694)	0.42
	Medicare versus private	0.855 (0.499, 1.465)	
	Other versus private	0.230 (0.009, 5.818)	
	Not insured versus private	0.143 (0.008, 2.652)	
Income	\$30–\$34,999 versus <\$30,000	0.974 (0.412, 2.306)	0.31
	\$35–\$45,999 versus <\$30,000	1.396 (0.608, 3.207)	
	≥\$46,000 versus <\$30,000	2.020 (0.801, 5.097)	
Education	20–28.9 versus ≥29 %	1.878 (0.910, 3.874)	0.07
	14–19.9 versus ≥29 %	0.946 (0.415, 2.158)	
	<14 versus ≥29 %	0.843 (0.361, 1.969)	
Facility type	Comp CCP versus CCP	1.545 (0.375, 6.372)	0.23
	Academic/Research versus CCP	2.191 (0.535, 8.977)	
Facility location	Middle Atlantic versus New England	0.837 (0.308, 2.272)	0.30
	South Atlantic versus New England	0.871 (0.320, 2.372)	
	East North Central versus New England	0.567 (0.204, 1.570)	
	East South Central versus New England	0.500 (0.146, 1.707)	
	West North Central versus New England	0.597 (0.183, 1.950)	
	West South Central versus New England	0.535 (0.161, 1.771)	
	Mountain versus New England	0.049 (0.003, 0.868)	
	Pacific versus New England	0.432 (0.132, 1.415)	
Charlson-Deyo	1 versus 0	0.592 (0.367, 0.956)	0.10
	2 versus 0	0.916 (0.386, 2.175)	
Grade	II versus I	1.684 (0.842, 3.367)	0.32
	III versus I	1.063 (0.448, 2.524)	
	IV versus I	0.462 (0.014, 15.479)	
Histology	PNET versus adenocarcinoma	2.168 (1.069, 4.395)	0.10
	Cystic versus adenocarcinoma	1.339 (0.414, 4.329)	
Tumor size (cm)	1–2 versus <1	1.874 (0.714, 4.919)	0.11
	2–3 versus <1	1.860 (0.699, 4.947)	
	3–4 versus <1	1.092 (0.375, 3.178)	
	4–5 versus <1	1.060 (0.353, 3.179)	
	>5 versus <1	0.856 (0.297, 2.467)	
Clinical stage	Stage 2 versus stage 1	0.836 (0.486, 1.438)	0.57
	Stage 3 versus stage 1	0.451 (0.085, 2.397)	
Path stage	Stage 2 versus stage 1	0.911 (0.523, 1.586)	0.75
	Stage 3 versus stage 1	0.230 (0.013, 3.936)	
	Stage 4 versus stage 1	0.755 (0.158, 3.605)	

greater than that for pancreaticoduodenectomy, which may skew the overall analysis. One of the potential limitations of the NCDB is that surgeries in which the approach was not specified by the operating surgeon may be grouped with the open procedures. The open approach is technically defined by the NCDB as open surgery as well as surgery with unspecified surgical approach. Therefore, the accuracy of conversion rates is unknown and has not been validated. There is a lack of granularity to the data in terms of hand-assisted MIS procedures or MIS surgeries which required extracorporeal anastomoses. Similar to surgeon preference or expertise with MIS, the individual patient preference or bias for a given surgical approach is not captured by the NCDB. The particular decision-making process for a given patient is complex and dependent on several intangible factors, which have been shown to influence treatment in the setting of colorectal cancer [45, 46]. This may also apply in the setting of pancreatic tumors. The NCDB does not record information regarding elective versus emergency surgery, whereby the latter would be considered a relative contraindication to performing either form of MIS [47]. Prior patient surgeries are not accounted for in the NCDB. Previous abdominal incision and the increased presence of intra-abdominal adhesions may potentially influence the decision-making process regarding surgical approach. Lastly, there is also the presence of missing information, which limits sample size and potentially influences the conclusions.

It is important to emphasize that the purpose of this study was only to identify disparities among patients who undergo open versus MIS approaches to pancreatic surgery and not to analyze the effects of these disparities on outcomes. An analysis of short-term (30-day) mortality is possible; however, this was not the focus of this study and therefore was not performed. At the time of this study, vital status was validated and released for patients up to December of 2006. An important future investigation will be to determine the impact of these disparities on long-term oncologic outcomes.

In conclusion, this study has identified important disparities in MIS for pancreatic tumors. As MIS becomes increasingly applied to pancreatic tumors and further study validates long-term equivalency of MIS as compared to open surgery with added short-term benefits, disparities in MIS may become more relevant to patient care. There is a substantial body of evidence reporting on racial and socioeconomic disparities in the treatment of pancreatic tumors. This study provides important contributions to the literature by characterizing important disparate associations with MIS and raises questions which may be addressed by public health policies to study further these disparities and their potential impact on care.

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Compliance with ethical standards

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