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ORIGINAL ARTICLE – PANCREATIC TUMORS

The Impact of Vascular Resection on Early Postoperative Outcomes after Pancreaticoduodenectomy: An Analysis of the American College of Surgeons National Surgical Quality Improvement Program Database

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ABSTRACT

Background. Several single-center reports suggest that vascular resection (VR) during pancreaticoduodenectomy (PD) for patients with pancreatic adenocarcinoma is feasible without affecting early postoperative mortality or morbidity. Our objective is to review the outcomes associated with VR during PD using a large multicenter data source.

Methods. A retrospective cohort analysis was performed using the National Surgical Quality Improvement Program Participant User Files for 2005–2009. All patients undergoing PD for a postoperative diagnosis of malignant neoplasm of the pancreas were included. Forward stepwise multivariate regression analysis was used to determine the association between VR during PD and 30-day postoperative mortality and morbidity after adjustment for patient demographics and comorbidities.

Results. 3,582 patients were included for analysis, 281 (7.8 %) of whom underwent VR during PD. VR during PD was associated with significantly greater risk-adjusted 30-day postoperative mortality [5.7 % with VR versus 2.9 % without VR, adjusted odds ratio (AOR) 2.1, 95 % confidence interval (CI) 1.22–3.73, $P = 0.008$] and overall morbidity (39.9 % with VR versus 33.3 % without VR, AOR 1.36, 95 % CI 1.05–1.75, $P = 0.02$). There was no significant difference in risk-adjusted postoperative mortality or morbidity between those patients undergoing VR by the primary surgical team versus those patients undergoing VR by a vascular surgical team.

Conclusions. Contrary to the findings of several previously published single-center analyses, the current study demonstrates increased 30-day postoperative morbidity and mortality in PD with VR when compared with PD alone.

Surgical resection remains the treatment of choice and only hope for long-term survival for patients with pancreatic cancer.[1–8] Complete clearance of macroscopic tumor with negative microscopic resection margins is the main surgical objective, as patients with residual disease demonstrate survival rates similar to those treated palliatively.[6,8–13] Debate has ensued in the literature regarding the resectability of tumors with local vascular involvement.[14–24] Numerous modern studies have supported the safety and feasibility of combining PD with vascular resection in an attempt to obtain negative margins; however, these reports have comprised almost exclusively single-center series with relatively small sample sizes.[15–17,19,21–31] To date, there has not been a large, multicenter study analyzing a uniform set of parameters to compare 30-day morbidity and mortality for PD with VR for pancreatic cancer versus PD without vascular resection. In the current study, we utilize a nationwide, multi-

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institutional database to report the largest series to date evaluating preoperative risk factors, intraoperative procedure characteristics (blood transfusion, length of procedure), morbidity, and mortality for PD with VR. Additionally, this is the first study of its kind to compare outcomes after PD with VR when the vascular resection was performed by a second surgical team (e.g., specialized vascular surgeons).

METHODS

The American College of Surgeons National Surgical Quality Improvement Program (NSQIP) Participant User Files for 2005–2009 were used for this analysis.[32,33] No patient or center identifiers were included. As such, the study was exempt from institutional review board (IRB) approval at our center. Patients were included for analysis if they met both of the following criteria: (1) primary Current Procedure Terminology code for pancreaticoduodenectomy (48150, 48152, 48153 or 48154), and (2) postoperative diagnosis of malignant neoplasm of the pancreas (International Classification of Diseases 9th edition codes 157, 157.0, 157.1, 157.2, 157.3, 157.4, 157.8 or 157.9).

The primary predictor variable for our analysis was the presence or absence of a vascular resection procedure during the index PD operation. The NSQIP database allows for the inclusion of up to 10 "other" procedures (aside from the index procedure) performed by the same surgical team during the index operation and for up to 10 "concurrent" procedures performed by other surgical teams during the index operation. For our analysis, patients were considered to have undergone vascular resection during their PD procedure if any of their "other" or "concurrent" procedure fields contained a Current Procedural Terminology (CPT) code of 35221 (direct repair of blood vessel, intra-abdominal), 35251 (direct repair of blood vessel with vein graft, intra-abdominal), 35281 (repair of blood vessel with graft other than vein, intra-abdominal), 35531 (bypass graft with vein, aortoceliac or aortomesenteric) or 35631 (bypass graft with other than vein, aortoceliac or aortomesenteric). Patients undergoing any other type of vascular procedure during their index operation were included in the "no vascular resection" group. We assume that all patients who underwent vascular resection were coded with an appropriate CPT code and that the CPT codes were accurately captured during the data accumulation process. Other predictor variables related to patient demographic information, comorbidities, and active medical conditions were also analyzed (panel).

Predictor variables for postoperative morbidity and mortality
Patient age
Gender
Body mass index (BMI)
American Society of Anesthesiologists (ASA) classification of 3 or greater
Diabetes mellitus requiring therapy with noninsulin agents or insulin
Current smoker within 1 year of operation
Greater than two drinks of ethanol per day in the 2 weeks prior to admission
Dyspnea upon moderate exertion or at rest
Ascites
Congestive heart failure
Chronic obstructive pulmonary disease
Hypertension requiring medical therapy
Coronary artery disease (including history of myocardial infarction within the past 6 months, prior percutaneous coronary intervention, prior cardiac surgery, and/or history of angina within 30 days prior to surgery)
Peripheral vascular disease (including history of revascularization or amputation for peripheral vascular disease and/or rest pain/gangrene)
Neurologic disease (including impaired sensorium, coma, hemiplegia/hemiparesis, history of transient ischemic attacks, stroke with neurologic deficit, tumor involving central nervous system, paraplegia/paraparesis, and/or quadriplegia/quadraparesis)
Preoperative wound infection
Disseminated cancer
Steroid use within 30 days prior to surgery for a chronic medical condition
Bleeding disorder
Chemotherapy for malignancy within 30 days prior to surgery
Radiotherapy for malignancy within 90 days prior to surgery
Preoperative systemic inflammatory release syndrome
Sepsis or septic shock
Resident participation in the operative procedure (assumed to represent a marker for hospital teaching status)

Preoperative variables that are tracked by NSQIP but which were not included in our analysis due to extremely low incidence (<0.5 % in both patient groups) included partially or totally dependent preoperative functional status, preoperative pneumonia, need for preoperative mechanical ventilation, esophageal varices, renal disease (including acute renal failure within 24 h prior to surgery and/or need for dialysis within 2 weeks prior to surgery), and need for preoperative transfusion. Several intraoperative variables were included as potential predictors of outcomes due to their potential reflection of overall procedure complexity. Tumor location within the pancreas

was not included as a variable for risk adjustment because this was not specified in a significant percentage of patients.

The primary outcome variables were 30-day postoperative mortality and overall 30-day postoperative morbidity. Secondary outcome variables included need for intraoperative transfusion, operative time, total work relative value units for the operation, specific postoperative complications (including superficial surgical-site infection, deep incisional surgical-site infection, organ/space surgical-site infection, wound dehiscence, pneumonia, unplanned reintubation, postoperative mechanical ventilation lasting >48 h, pulmonary embolism, urinary tract infection, progressive renal insufficiency, acute renal failure requiring dialysis, stroke, coma lasting >24 h, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, bleeding requiring more than four units of packed red blood cells (PRBC) within 72 h of the index procedure, failure of graft or prosthesis requiring interventions, peripheral nerve injury, deep venous thrombosis, sepsis, or septic shock), need for reoperation within 30 days, and postoperative length of hospitalization.

Comparisons of preoperative variables for patients undergoing PD with and without vascular resection were made using Pearson's Chi-square tests for categorical variables and Mann–Whitney rank-sum tests for continuous variables. Comparisons of the primary and secondary outcomes for the two groups were made in the same manner. For each primary outcome variable (30-day postoperative mortality and morbidity), all potential preoperative variables were considered for inclusion in a forward stepwise multivariate logistic regression model, using p value <0.05 as the entry criterion. As the primary predictor of interest, presence or absence of vascular resection was forced as a variable into both of these regression models.

A second analysis was conducted on that subgroup of patients undergoing vascular resection during their PD procedure, with select preoperative, intraoperative, and postoperative variables being compared between those patients whose vascular resection was performed by the primary surgical team and those patients whose vascular resection was performed by a separate vascular surgical team. Patients were assigned to the "primary team" group if one of the aforementioned CPT codes indicating a vascular resection procedure was recorded in NSQIP as having been performed by the primary team, while patients were assigned to the "vascular team" group if the vascular resection CPT code was recorded in NSQIP as having been performed by some team other than the primary surgical team. Patients who were recorded as having a vascular resection procedure performed both by the primary surgical team and by a separate vascular team were excluded from this subgroup analysis. Preoperative characteristics and select postoperative outcomes between the two groups were compared using Pearson's Chi-square tests for categorical variables and Wilcoxon rank-sum tests for continuous variables. Differences in primary outcome measures (30-day postoperative mortality and morbidity) for the two groups were adjusted for preoperative patient characteristics using forward stepwise regression as described previously, with the predictor variable of interest in this subgroup analysis (second surgical team performing vascular resection procedure) being forced into the models. All statistical analyses were performed using Stata version 11.0 (College Station, TX).

RESULTS

A total of 3,582 patients undergoing pancreaticoduodenectomy for malignant neoplasm of the pancreas were included for analysis. Of these, 281 patients were identified as undergoing a procedure consistent with intra-abdominal vascular resection during PD. A comparison of the demographic and comorbid characteristics between patients with and without vascular resection is shown in Table 1. The "vascular resection" group demonstrated a statistically significant increase in the incidence of diabetes mellitus, weight loss (>10 % loss body weight in preceding 6 months), preoperative radiotherapy, and resident participation. BMI was significantly increased in the "no vascular resection" group. There was no significant difference in the remaining preoperative characteristics including age, gender, and incidence of pre-existing cardiopulmonary disease.

Thirty-day postoperative mortality was 5.7 % in patients undergoing pancreaticoduodenectomy with intra-abdominal vascular resection, compared with 2.9 % for patients undergoing the procedure without vascular resection [adjusted odds ratio (AOR) 2.1, 95 % confidence interval (CI) 1.22–3.73, $P = 0.008$]. After adjustment for patient demographic characteristics and comorbid conditions, the association between vascular resection during pancreaticoduodenectomy and postoperative mortality and morbidity retained significance (Fig. 1). Addition of vascular resection to pancreaticoduodenectomy resulted in significantly increased overall morbidity (39.9 % with VR versus 33.3 % without VR, AOR 1.36, 95 % CI 1.05–1.75, $P = 0.02$) with longer operative times, more complex procedures (as indicated by the total work relative value units), and greater need for intraoperative packed red blood cell transfusion (Table 2). The overall morbidity rates refer to the percentage of patients who suffered 1 or more of the 21 specific complications that are tracked by NSQIP and listed in Table 2 as "specific complications" (note that

TABLE 1 Preoperative and intraoperative characteristics of patients undergoing pancreaticoduodenectomy with and without vascular resection

Preoperative characteristic	No vascular resection ($n = 3,301$)	Vascular resection ($n = 281$)	P value
Age in years (mean ± SD)	65.6 ± 11.4	65.5 ± 11.2	0.99
Female	1,600 (48.5 %)	143 (50.9 %)	0.44
Body mass index in kg/m^2 (mean ± SD)	26.5 ± 5.8	26.0 ± 5.6	0.05*
ASA classification ≥3	2,333 (70.7 %)	213 (75.8 %)	0.07
Diabetes mellitus	851 (25.8 %)	93 (33.1 %)	0.01*
Tobacco use	696 (21.1 %)	71 (25.3 %)	0.10
Heavy ethanol use	94 (2.9 %)	10 (3.6 %)	0.50
Dyspnea	283 (8.6 %)	22 (7.8 %)	0.67
Chronic obstructive pulmonary disease	145 (4.4 %)	10 (3.6 %)	0.51
Ascites	29 (0.9 %)	1 (0.4 %)	0.36
Congestive heart failure	11 (0.3 %)	2 (0.7 %)	0.31
Coronary artery disease	403 (12.2 %)	28 (10.0 %)	0.27
Peripheral vascular disease	50 (1.5 %)	3 (1.1 %)	0.55
Hypertension	1,812 (54.9 %)	138 (49.1 %)	0.06
Neurologic disorder	182 (5.5 %)	13 (4.6 %)	0.53
Disseminated cancer	67 (2.0 %)	8 (2.9 %)	0.36
Preoperative infected wound	34 (1.0 %)	2 (0.7 %)	0.61
Steroids	64 (1.9 %)	6 (2.1 %)	0.82
Weight loss	766 (23.2 %)	80 (28.5 %)	0.05*
Bleeding disorder	80 (2.4 %)	7 (2.5 %)	0.94
Chemotherapy in past 30 days	73 (2.2 %)	10 (3.6 %)	0.15
Radiotherapy in past 90 days	109 (3.3 %)	23 (8.2 %)	<0.01*
Preoperative SIRS/sepsis/shock	88 (2.7 %)	9 (3.2 %)	0.59
Resident participation	2,801 (84.9 %)	252 (89.7 %)	0.03*

SD standard deviation, *ASA* American Society of Anesthesiologists, *SIRS* systemic inflammatory response syndrome

* $p \leq 0.05$

adding the "specific complications" incidence rates from Table 2 will yield a percentage for each patient group that is higher than the "overall morbidity rate" from Fig. 1, as some patients in either group suffered more than one specific complication). Specific complications with a higher rate of event occurrence in patients undergoing VR included prolonged postoperative mechanical ventilation (10.7 % versus 5.4 %, $P < 0.0001$), postoperative bleeding within 72 h of surgery (3.2 % versus 1.2 %, $P = 0.005$), postoperative deep venous thrombosis (1.9 % versus 5.0 %, $P = 0.001$), and reoperation (13.2 % versus 7.0 %, $P < 0.0001$) (Table 2). There was no significant difference between the two groups in median postoperative length of hospitalization.

Of the 281 patients undergoing vascular resection, 187 (66.5 %, "primary team") were reported by NSQIP to have undergone the procedure by the primary surgical team while 88 (31.3 %, "vascular team") were reported to have undergone the procedure by a separate surgical team. Six patients had vascular resection CPT codes performed by both the primary team and a separate team and were therefore excluded from secondary analysis. There was little clinical or statistical difference in the demographic or comorbid characteristics of the two groups of patients (Table 3). The two groups did not differ significantly in 30-day postoperative mortality or morbidity either before or after adjustment for demographic variables and comorbid diagnoses (Table 4). Pancreaticoduodenectomies in which the vascular team performed the vascular resection procedure lasted significantly longer than those in which the primary team performed the resection, were more likely to require intraoperative packed red blood cell transfusion, and resulted in significantly longer median postoperative hospitalization (Table 4); however, information regarding the clinical context of the procedure (e.g., planned vascular resection versus unplanned secondary to vascular injury) was not available in the NSQIP dataset. There were no significant differences between the two groups in the incidence of postoperative bleeding or need for early reoperation.

DISCUSSION

The feasibility and associated morbidity and mortality of combined vascular resection with pancreaticoduodenectomy for pancreatic cancer remain important concerns for the surgical oncologist. The current study increases the body of evidence in this field by reporting the largest series to date

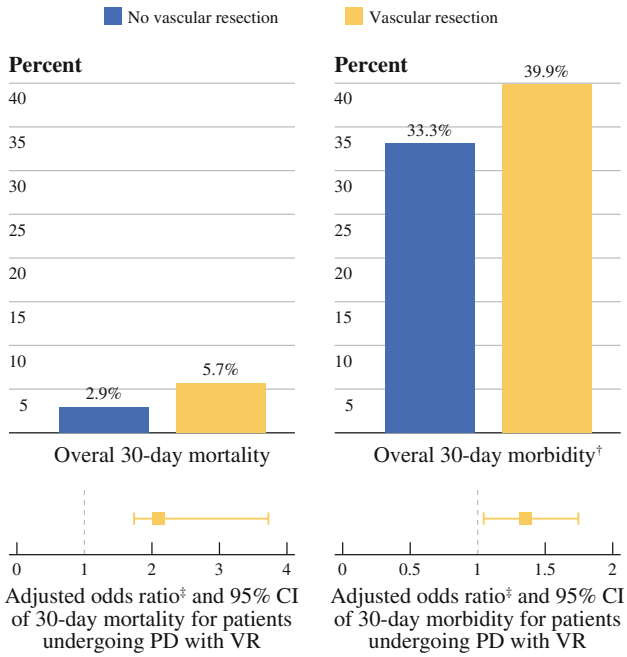

FIG. 1 Thirty-day mortality and morbidity for patients undergoing pancreaticoduodenectomy with and without vascular resection. † Overall morbidity encompasses any patients experiencing one of the "specific complications" listed in Table 2. ‡Adjusted for patient team performing vascular resection, patient age, gender, body mass index, American Society of Anesthesiologists classification, diabetes mellitus, ongoing tobacco use, heavy ethanol use, dyspnea, history of chronic obstructive pulmonary disease, ascites, history of congestive heart failure, coronary artery disease, peripheral vascular disease, hypertension, neurologic disorder, disseminated cancer, preoperative infected wound, chronic steroid use, weight loss, bleeding disorder, preoperative chemotherapy and/or radiotherapy, preoperative systemic inflammatory response syndrome/sepsis/septic shock, or presence of a surgical resident during the pancreaticoduodenectomy procedure. *PD* pancreaticoduodenectomy, *VR* vascular resection, *CI* confidence interval

analyzing PD with VR, incorporating mortality data with a comprehensive review of preoperative/intraoperative characteristics and postoperative complications.

Several studies have well summarized the literature to date documenting outcomes of PD with VR for pancreatic cancer. Siriwardana et al. performed a systematic review of outcome of synchronous portal–superior mesenteric vein resection during pancreatectomy for cancer.[34] Their analysis evaluated a total 52 studies encompassing 1,646 patients undergoing VR. The median (range) number of patients undergoing VR was 23 (4–172). Thirty-nine of the studies (1,235 patients) provided mortality data after PD with VR, while 24 of the studies (851 patients) contained data on postoperative complications. The median morbidity rate for patients undergoing PD with VR was 42 %, and the mortality rate was 5.9 %. These studies were almost exclusively single-center reports, with approximately 90 % of publications including fewer than 60 patients undergoing PD with VR. Seventeen of the studies were performed in America (Table 5).[6,16,21,27,35–47]

A more recent study by Ramacciato et al. documented a systematic review of PD with VR from January 2000 to March 2008, reflecting what the authors believed to be the current status of pancreatic surgery for cancer invading the portal vein (PV)/superior mesenteric vein (SMV).[19] Studies where data about PM/SMV resection were not separable from data about more extended vascular resections (i.e., arterial, inferior vena cava) were excluded. Twelve studies met inclusion criteria (Table 5).[17,22,26,40,48–55] Postoperative complication rates for PD with VR ranged from 16.7 % to 54 %, while perioperative mortality rates ranged from 0 % to 7.7 %. Eight studies that compared morbidity rates after PD with or without VR reported no difference between the two procedures in complication rate. Similar to the previous systematic review, the studies analyzed were almost exclusively isolated single-institutional series. All but one of the articles in the study population included a sample size of fewer than 50 patients undergoing PD with VR.

Our analysis suggests that vascular resection is associated with an increased risk of 30-day postoperative death or complications after pancreaticoduodenectomy. Importantly, patients undergoing PD with VR had roughly double the incidence of significant bleeding postoperatively, reoperation, prolonged ventilator support, postoperative deep vein thrombosis, and perioperative morality. These data are in contrast to the majority of previously published studies evaluating this procedure. The overwhelming majority of previous studies represent single-institution series at high-volume centers. The divergence in our reported outcomes from previous studies may reflect a publication bias from large, single-center institutions.[56] Additionally, the sample size and scope of postoperative complications evaluated in the current study exceed most previous reports, therefore allowing a more in-depth assessment of overall morbidity/mortality associated with this procedure that may be undetected in smaller series. Inferior morbidity and mortality associated with VR may be unrelated to surgical technique, but rather reflect a more advanced or aggressive underlying disease process in those patients. Overall, however, outcomes following PD with VR were comparable to previous reports of major cancer operations commonly performed.[19,34,57,58]

Surgical subspecialization continues to be a controversial trend in contemporary surgical practice.[57–62] Vascular surgeon collaboration during PD requiring VR has been proposed in the literature.[31] This is the first study of its kind to compare outcomes when the primary surgical oncology team performed the vascular resection versus a second surgical team (e.g., specialized vascular surgeons). Our

TABLE 2 Intraoperative and postoperative outcomes for patients undergoing pancreaticoduodenectomy with and without vascular resection

Secondary outcome measure	No vascular resection ($n = 3,301$)	Vascular resection ($n = 281$)	p Value
Operative time in min (mean ± SD)	377 ± 123	497 ± 142	<0.01*
Intraoperative PRBC transfusion	1,114 (33.8 %)	147 (52.3 %)	<0.01*
Total WRVUs	65 ± 17	108 ± 27	<0.01*
Specific complications			
Superficial surgical-site infection	314 (9.5 %)	30 (10.7 %)	0.53
Deep surgical-site infection	74 (2.2 %)	2 (0.7 %)	0.09
Organ/space surgical-site infection	278 (8.4 %)	25 (8.9 %)	0.78
Wound dehiscence	63 (1.9 %)	4 (1.4 %)	0.57
Pneumonia	161 (4.9 %)	20 (7.1 %)	0.10
Unplanned reintubation	164 (5.0 %)	19 (6.8 %)	0.19
Pulmonary embolism	35 (1.1 %)	2 (0.7 %)	0.58
Prolonged ventilatory support	179 (5.4 %)	30 (10.7 %)	<0.01*
Progressive renal insufficiency	19 (0.6 %)	1 (0.4 %)	0.64
Acute renal failure	34 (1.0 %)	5 (1.8 %)	0.25
Urinary tract infection	168 (5.1 %)	18 (6.4 %)	0.34
Stroke	15 (0.5 %)	1 (0.4 %)	0.81
Coma >24 h	4 (0.1 %)	3 (1.1 %)	<0.01*
Peripheral nerve injury	1 (0.03 %)	0 (0 %)	0.77
Cardiac arrest	39 (1.2 %)	8 (2.9 %)	0.02*
Myocardial infarction	18 (0.6 %)	2 (0.7 %)	0.72
Bleeding within 72 h	39 (1.2 %)	9 (3.2 %)	0.01*
Graft/prosthetic failure	2 (0.1 %)	1 (0.4 %)	0.10
Deep venous thrombosis	63 (1.9 %)	14 (5.0 %)	<0.01*
Sepsis	339 (10.3 %)	23 (8.2 %)	0.27
Septic shock	144 (4.4 %)	17 (6.1 %)	0.19
Return to operating room	230 (7.0 %)	37 (13.2 %)	<0.01*
Median (IQR) and mean length of postoperative hospital stay	9 (7–14) 12.6 ± 10.8	10 (7–14) 14.0 ± 13.3	0.08

SD standard deviation, *PRBC* packed red blood cell, *WRVU* work relative value unit, *IQR* interquartile range

* $p \leq 0.05$

data showed equivalent morbidity and mortality regardless of whether multiple surgical teams were involved; however, operative time and intraoperative PRBC transfusion were significantly increased in such cases, which may reflect the complexity of these operations or the clinical context (e.g., emergent intraoperative consult) that required additional surgical expertise. Although a limitation to this subanalysis is the inability to determine surgeon experience, these results nonetheless inform the debate on subspecialist involvement by reporting no difference in 30-day mortality when operations involving specialized vascular surgeons were compared with all other vascular resections. While our study was not designed to definitively comment on the advisability of involving a specialized surgical team for the vascular resection portion of PD requiring VR, our data do not indicate that such collaboration is required for optimal outcomes.

These results should be interpreted in the context of the limitations to the analysis. First, PD with VR for indications other than pancreatic cancer was not evaluated, and our study also did not evaluate outcomes past 30 days. In this investigation we are limited to the data available in the NSQIP database, and this study relies on CPT codes for accuracy and completeness in identifying cases where PD included VR. Tumor characteristics including histology, size, location, and resection margin as well as specific details of the vascular resection and reconstruction technique (e.g., patch repair versus interposition graft) or the clinical context (e.g., planned versus unplanned) are not included in our data source. Additionally, specific complications related to pancreatic surgery, such as pancreatic leak and delayed gastric emptying, are not captured by NSQIP during the time period of our analysis. NSQIP data are submitted from hospitals that are participating in the NSQIP and may not be a nationally representative sample. A further limitation to our analysis is that these data are de-identified as to hospital characteristics such as size, procedural volume, and teaching status, which obviates our ability to assess potential outliers from low-volume centers. The smaller sample of patients undergoing PD with VR

TABLE 3 Demographic and comorbid characteristics for subgroup of patients undergoing pancreaticoduodenectomy with vascular resection

Preoperative characteristic	Primary team ($n = 187$)	Vascular team ($n = 88$)	*P* Value
Age in years (mean ± SD)	66.5 ± 10.9	63.5 ± 11.6	0.055
Female	94 (50.3 %)	45 (51.1 %)	0.89
Body mass index in kg/m^2 (mean ± SD)	26.2 ± 5.7	25.4 ± 5.0	0.3
ASA classification ≥3	140 (74.9 %)	68 (77.3 %)	0.67
Diabetes mellitus	70 (37.0 %)	23 (26.1 %)	0.07
Tobacco use	55 (29.4 %)	15 (17.1 %)	0.03
Heavy ethanol use	5 (2.7 %)	5 (5.7 %)	0.21
Dyspnea	18 (9.6 %)	4 (4.6 %)	0.15
Chronic obstructive pulmonary disease	7 (3.7 %)	3 (3.4 %)	0.89
Ascites	0 (0 %)	1 (1.1 %)	0.14
Congestive heart failure	1 (0.5 %)	1 (1.1 %)	0.58
Coronary artery disease	20 (10.7 %)	6 (6.8 %)	0.31
Peripheral vascular disease	3 (1.6 %)	0 (0 %)	0.23
Hypertension	95 (50.8 %)	37 (42.1 %)	0.18
Neurologic disorder	8 (4.3 %)	4 (4.6 %)	0.92
Disseminated cancer	3 (1.6 %)	5 (5.7 %)	0.06
Preoperative infected wound	2 (1.1 %)	0 (0 %)	0.33
Steroids	5 (2.7 %)	1 (1.1 %)	0.42
Weight loss	52 (27.8 %)	27 (30.7 %)	0.62
Bleeding disorder	4 (2.1 %)	3 (3.4 %)	0.53
Chemotherapy in past 30 days	8 (4.3 %)	2 (2.3 %)	0.41
Radiotherapy in past 90 days	13 (7.0 %)	10 (11.4 %)	0.22
Preoperative SIRS/sepsis/shock	7 (3.7 %)	2 (2.3 %)	0.52
Resident participation	164 (87.7 %)	82 (93.2 %)	0.17

SD standard deviation, *ASA* American Society of Anesthesiologists, *SIRS* systemic inflammatory response syndrome

TABLE 4 Intraoperative and postoperative outcomes for subgroup of patients undergoing pancreaticoduodenectomy with vascular resection

Outcome measure	Primary team ($n = 187$)	Vascular team ($n = 88$)	*P* Value	Adjusted odds ratio (95 % CI) for vascular team participaton[a, b]
30-Day postoperative mortality	8 (4.3 %)	7 (8.0 %)	0.21	2.68 (0.87, 8.22)
30-Day postoperative morbidity	71 (38.0 %)	38 (43.2 %)	0.41	1.34 (0.79, 2.26)
Operative time in min (mean ± SD)	481 ± 144	530 ± 132	0.002	–
Intraoperative PRBC transfusion	84 (44.9 %)	57 (64.8 %)	0.002	–
Bleeding within 72 h	5 (2.7 %)	4 (4.6 %)	0.42	–
Return to operating room	23 (12.3 %)	12 (13.6 %)	0.76	–
Median (IQR) and mean length of postoperative hospital stay	9 (7–14) 12.6 ± 11.6	12 (8–18.5) 16.9 ± 16.2	0.0008	–

[a] Risk-adjusted multivariate analysis performed for the primary outcome measures of 30-day postoperative morbidity and mortality only

[b] Adjusted for patient team performing vascular resection, patient age, gender, body mass index, American Society of Anesthesiologists classification, diabetes mellitus, ongoing tobacco use, heavy ethanol use, dyspnea, history of chronic obstructive pulmonary disease, ascites, history of congestive heart failure, coronary artery disease, peripheral vascular disease, hypertension, neurologic disorder, disseminated cancer, preoperative infected wound, chronic steroid use, weight loss, bleeding disorder, preoperative chemotherapy and/or radiotherapy, preoperative systemic inflammatory response syndrome/sepsis/septic shock, or presence of a surgical resident during the pancreaticoduodenectomy procedure

CI confidence interval, *SD* standard deviation, *IQR* interquartile range

(281 versus 3,301) also increases the potential impact of outliers in this group compared with patients undergoing PD alone. Despite these limitations, however, the volume of patients included in our study relative to previous reports in the literature as well as the scope of outcome measures analyzed provides important information for patients and

TABLE 5 Previous studies evaluating pancreatic resection with vascular resection

Study	Years	Inclusion period	Total patients	Pancreatic resection with VR
Fortner et al.[36–38]	1983–4, 1996	1972–1982	97	56
Sindelar.[43]	1989		20	20
Tsao et al.[44]	1994	1979–1992	106	10
Fernandez-del Castillo et al.[35]	1995	1991–1994	231	10
Yeo et al.[47]	1995	1984–1999	616	15
Harrison et al.[16]	1996	1983–1995	332	58
Leach et al.[41]	1998	1990–1997	204	56
Horvath and Chabot[39]	1999	1991–1998	25	4
Wanebo et al.[46]	2000	1990–1992	9	6
Machado et al.[42]	2001	1996–1999	15	15
Shibata et al.[22]	2001	1983–1998	74	28
Kawada et al.[17]	2002	1990–1997	43	28
Sasson et al.[21]	2002	1987–2000	116	16
Capussotti et al.[26]	2003	1988–1998	100	22
Howard et al.[40]	2003		36	13
Nakagohri et al.[51]	2003	1992–2001	81	33
Poon et al.[52]	2004	1998–2002	50	12
Tseng et al.[45]	2004	1990–2002	291	110
Jain et al.[49]	2005	1982–2004	48	48
Zhou et al.[55]	2005	1999–2003	32	32
Riediger et al.[53]	2006	1994–2004	125	40
Shimada et al.[54]	2006	1996–2004	149	86
Al-Haddad et al.[48]	2007	1998–2005	76	22
Kurosaki et al.[50]	2008	1987–2005	77	35

VR vascular resection

Adapted from Siriwardana et al. (2006)[34] and Ramacciato et al. (2009)[19]

clinicians considering surgery for locally advanced disease, and can better inform these decisions.

CONCLUSIONS

The findings of our analysis suggest that addition of vascular resection to pancreaticoduodenectomy for pancreatic adenocarcinoma is associated with increased risk of early postoperative morbidity and mortality.

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