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Pancreaticoduodenectomy outcomes for locally advanced right colon cancers: A systematic review

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ABSTRACT

Background: Pancreaticoduodenectomy (PD) with right hemicolectomy (RH) to treat locally advanced right colon cancer (LARCC) has been rarely reported in the literature. Herein, we characterize clinicopathologic factors and evaluate outcomes of en bloc PD and RH for LARCC.

Methods: A systematic review of the literature was conducted on PubMed using MeSH terms ("pancreaticoduodenectomy" or "pancreas/surgery" or "duodenum/surgery" or "colectomy") and ("colonic neoplasms"). Data was extracted from patients who underwent en bloc PD and RH for LARCC. Factors investigated included patient demographics, surgical and pathologic parameters, postoperative complications, disease recurrence, and survival.

Results: Our search yielded 27 articles (106 patients), including 1 case from our institution. Most patients were male (62.1%), median age 58 years (range 34–83). Surgical procedures performed included en bloc RH with PD ($n = 91$, 85.8%) and en bloc RH with pylorus-preserving PD ($n = 15$, 14.2%). Among reported, 95.5% of patients ($n = 63$), underwent R0 resection. One or more complications were reported in 33 patients (52.4%). Median survival was 168 months. Survival after resection was 75.9% at 2 years and 66.3% at 5 years. Overall survival was greater in patients with no lymph node involvement (IIC versus IIIC, hazard ratio 8.4, $P = .003$). Five-year survival for patients was 84.9% in patients with stage IIC versus 46.4% in patients with stage IIIC. There were 3 postoperative mortalities.

Conclusion: This data demonstrates that en bloc PD and RH is rarely performed yet can be a potentially safe treatment option in patients with LARCC. Lymph node involvement was the only independent prognostic factor.

Colorectal cancer is the second most common cause of cancer related deaths in the United States occurring equally in both men and women.[1,2] With an estimated incidence of 145,600 cases each year and a mortality rate of 51,020 patients annually, it remains a difficult prognosis.[2] Current standard therapy ranges from polypectomy to partial or total resection with en bloc lymphadenectomy, with or without adjuvant chemotherapy.[3,4] Up to 20 percent of colon cancer cases present with locally advanced disease, necessitating more complex surgical approaches to achieve R0 resection.[5]

Pancreaticoduodenectomy (PD) is a procedure typically performed to address diseases involving the pancreatic head and periampullary region.[6] Previous studies have shown that in patients with locally advanced right colon cancer (LARCC) with invasion of the pancreas or duodenum, en bloc PD along with right hemicolectomy (RH) can be performed to achieve oncologic resection.[7–33] However, hesitancy to perform this complex multivisceral resection may be attributed to lack of thorough analysis of surgical outcomes, postoperative complications, and survival data.[21]

We aim to review published studies detailing this procedure to characterize preoperative, intraoperative, and postoperative clinicopathologic variables of interest and evaluate efficacy and safety of en bloc PD with RH for LARCC.

Methods

A systematic review (Fig 1) was performed according to the PRISMA statement.[34] A MEDLINE search was conducted using

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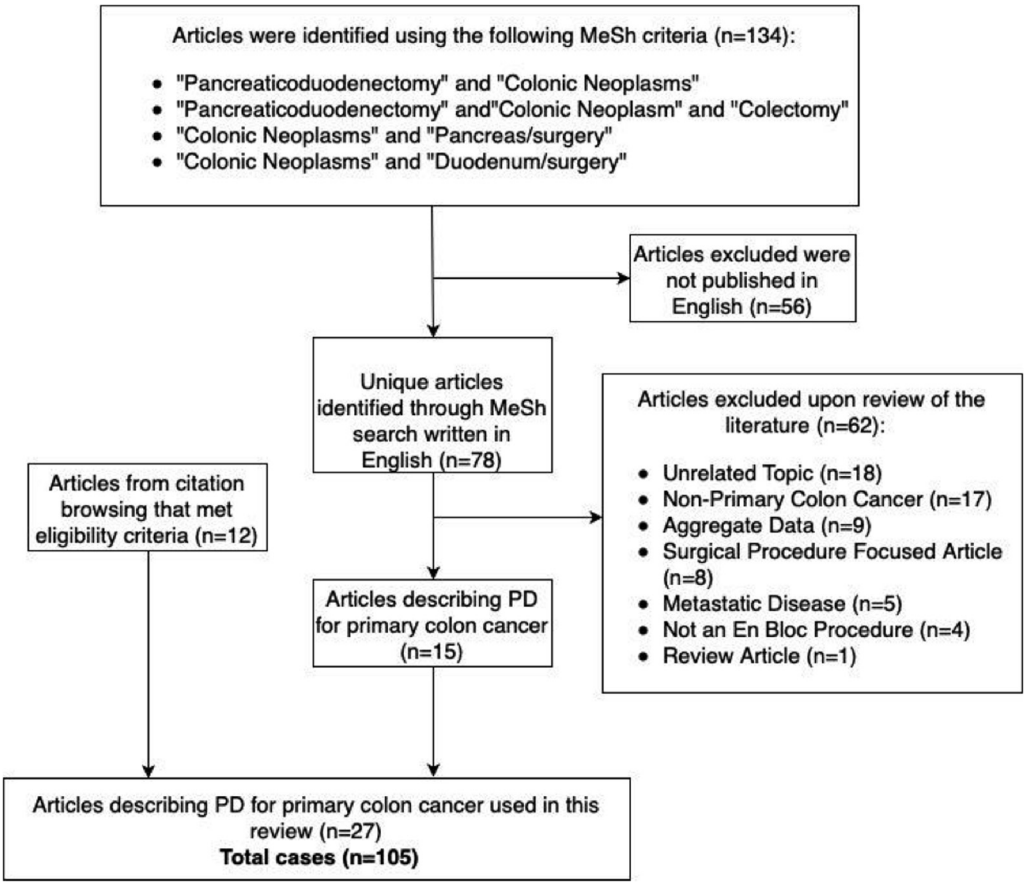

Fig 1. PRISMA diagram of systematic literature review. The initial search resulted in 78 unique articles written in English. A total of 62 articles reporting pancreaticoduodenectomy performed for reasons other than localized primary colon cancer (ie, pancreatic cancer or metastatic disease) and articles from which individual patient data could not be extrapolated were excluded, yielding a total of 15 articles. An additional 12 articles were found upon review of references. A total of 27 articles containing 105 patient cases are included in our systematic review from the world literature. One additional case from our institution results in a total ($n = 106$).

MeSH search terms "pancreaticoduodenectomy," "colonic neoplasms," "colectomy," "pancreas/surgery," and "duodenum/surgery." Inclusion criteria were case reports and case series describing PD for patients with primary colon cancers. We excluded articles that were not published in English, articles that described PD for noncolonic primary neoplasms, patients with metastatic disease, and articles from which individual patient data could not be extrapolated. Articles that did not specify source of patient information were excluded from our patient cohort to prevent inclusion of duplicated series. Only patients with contiguous locally advanced disease with direct extension of the primary tumor were included. Upon applying this eligibility criteria, we narrowed our search to 15 articles. An investigation of references from our initial MeSH search provided an additional 12 articles that met our criteria for a total to 27 articles (Fig 1).

In our review, we collected all relevant patient information from these articles in a systematic manner and compiled our findings into a database for analysis. Factors investigated included patient presentation, tumor staging and location, surgical parameters and procedures, postoperative complications, resection margins, histopathologic features, disease recurrence, and follow-up time. All cases were restaged according to the 8th edition of American Joint Committee on Cancer (AJCC). We were able to obtain individual follow-up data with information about whether each patient was alive or dead for 103 patients (2 died of postoperative complications without reporting number of days or months survived postoperatively and a third patient was alive with unknown status of follow-up).

Survival rate estimates were calculated with the use of Kaplan-Meier method and compared with the use of a stratified log-rank test. A Cox proportional-hazard model was used to estimate hazard ratios with 95% confidence intervals. Missing data was not imputed. Univariable analysis was performed for age, sex, stage, margins, chemotherapy, estimated blood loss (EBL), and histopathology because previous studies have highlighted their impact on survival. On multivariable analysis we excluded variables with the highest number of missing values (EBL, histopathology, margins). Margin status was excluded due to the low n in the R1 category. The multivariable analysis was run as a backward stepwise Cox Regression. All data was analyzed using the IBM SPSS Statistics 25.0 software (Armonk, NY).

Results

Twenty-seven publications from 1980 to 2017 with information on 105 cases that met our inclusion criteria were included in this review. An additional case was included from our institution for a total of 106 cases.

The majority of patients were male (62.1%) with a median age of 58 years (range 34–83). Data pertaining to symptomatology could be extrapolated for 46 patients. The majority of our patient cohort ($n = 97$, 95.1%) had surgery performed at a tertiary or academic center. The most common presenting symptoms were palpable abdominal mass ($n = 20$, 43.5%), anemia ($n = 20$, 43.5%), abdominal pain ($n = 19$, 41.3%), and weight loss ($n = 17$, 37.0%). Only 64 cases

Table I
Demographic and clinical characteristics of patients

Characteristic	
Age ($n = 103$)	
Median (range), y	58 (34–83)
Sex ($n = 103$), no. (%)	
Male	63 (62.1)
Female	39 (37.9)
Presentation ($n = 46$), no. (%)	
Abdominal pain	19 (41.3)
Abdominal mass	17 (37.0)
Anemia	15 (32.6)
Weight loss	12 (26.1)
Altered bowel habits	5 (10.9)
GI bleeding	5 (10.9)
Diarrhea	5 (10.9)
Vomiting	4 (8.7)
Abdominal distention	4 (8.7)
Incidental discovery	2 (4.3)
Duodenocolic fistula	2 (4.3)
Constipation	1 (2.2)
Bowel obstruction	1 (2.2)
Fatigue	1 (2.2)
Decreased appetite	1 (2.2)
Pale skin/mucosa	1 (2.2)
RUQ pain	1 (2.2)
Modality of diagnosis ($n = 64$), no. (%)	
Computed tomography (abdominal)	53 (82.8)
Colonoscopy	38 (59.3)
Biopsy	33 (51.6)
Upper endoscopy	25 (39.1)
Exploratory laparotomy	7 (10.9)
Barium enema	3 (7.8)
Duodenography	2 (3.1)
Lab results	1 (1.6)

GI, gastrointestinal; *RUQ*, right upper quadrant.

reported one or more modality of diagnosis. The most commonly used preoperative diagnostic modality was computed tomography scan ($n = 53$, 82.8%; Table I). The median preoperative carcinoembryonic antigen ($n = 33$) was 6.30 ng/mL (range 0.5–188.91 ng/mL).

Staging of tumors was assigned to all cases as per the 8th edition of AJCC staging system for colorectal cancer.[35] Fifty-nine (55.7%) tumors were classified as IIC and ($n = 47$, 44.3%) were stage IIIC. Location of the tumor was described in 86 cases. The majority of tumors were located at the hepatic flexure ($n = 47$, 54.7%) and ascending colon ($n = 21$, 24.4%). Information regarding tumor invasion was available for 96 cases, with the most common site of invasion being duodenum ($n = 74$, 77.1%), pancreas ($n = 37$, 38.5%), liver ($n = 11$, 11.5%), and stomach ($n = 10$, 10.4%). Twelve cases (12.5%) confirmed invasion but did not specify site of invasion. Although many cases reported on lymph node status, only 12 cases reported on the number of lymph nodes harvested with median number harvested being 40 (range 10–61). Lymph nodes were positive in 54 patients (50.9%). Of those reported with positive nodes and exact counts ($n = 20$), the median number of positive lymph nodes was 3 (range 1–20). The median maximum tumor diameter ($n = 51$) was 9.0 cm (5–0 cm). Ninety-three cases reported histopathologic classifications: adenocarcinoma not otherwise specified (NOS, $n = 81$, 87.1%), mucinous ($n = 11$, 11.8%), and neuroendocrine ($n = 1$, 1.1%; Table II).

Surgical procedures performed included en bloc RH and PD ($n = 91$, 85.8%) and en bloc RH and pylorus-preserving PD ($n = 15$, 14.2%). Concurrent procedures specified included right nephrectomy ($n = 4$, 3.8%), superior mesenteric vein (SMV) resection ($n = 3$, 2.8%), liver resection ($n = 2$, 1.9%), hepatic bisegmentectomy ($n = 2$, 1.9%), distal pancreatectomy ($n = 1$, 0.9%), and resection of Meckel's diverticulum ($n = 1$, 0.9%). All concurrent procedures, including

Table II
Tumor characteristics

Characteristic	
Stage ($n = 106$), no. (%)	
IIC	59 (55.7)
IIIC	47 (44.3)
Tumor location ($n = 86$), no. (%)	
Hepatic flexure	47 (54.7)
Ascending colon	21 (24.4)
Transverse colon	12 (13.9)
Hepatic flexure and transverse colon	5 (5.8)
Hepatic flexure and ascending colon	1 (1.2)
Site of invasion ($n = 96$), no. (%)	
Duodenum	74 (77.1)
Pancreas	37 (38.5)
Unspecified	12 (12.5)
Liver	11 (11.5)
Stomach	10 (10.4)
Right kidney	8 (8.3)
Gallbladder	7 (7.3)
Abdominal wall	6 (6.3)
SMV	5 (5.2)
Lymph nodes ($n = 106$), no. (%)	
Positive	54 (50.9)
Tumor diameter ($n = 51$)	
Median (range; cm)	9 (5–20)
Histopathologic type ($n = 93$), no. (%)	
Adenocarcinoma NOS	81 (87.1)
Mucinous	11 (11.8)
Neuroendocrine	1 (1.1)

SMV, superior mesenteric vein.

liver resections, were performed for locally advanced disease with direct extension of the primary tumor. R0 resection was confirmed in the majority of patients who reported on resection margins ($n = 63$, 95.5%). The median operative time ($n = 43$) was 400 min (range 127–750 min). The median EBL ($n = 33$) was 500 mL (range 100–2,760 mL; Table III).

Data regarding postoperative complications was reported for a total of 63 patients (Table IV). Thirty (47.6%) patients reportedly had no complications. The most common complication was pancreatic fistula ($n = 15$, 23.8%), followed by delayed gastric emptying ($n = 11$, 17.5%). Eight patients (12.6%) were reported to have postoperative infection, four (6.3%) of which were abdominal abscesses.

Twenty-seven patients (42.9%) had recurrent disease (Table IV). Of the 27 patients with recurrence, only 12 cases specified the location: liver ($n = 5$, 50%), retroperitoneum ($n = 2$, 20%), systemic ($n = 2$, 20%), and peritoneum and ileum each had one incidence ($n = 1$, 10%). Of the 27 patients who recurred, 9 patients had

Table III
Operative characteristics and surgical parameters

Characteristic	
Surgical procedure ($n = 106$), no. (%)	
Right hemicolectomy and PD	91 (85.8)
Right hemicolectomy and PPPD	15 (14.2)
Right nephrectomy	4 (3.8)
SMV resection	3 (2.8)
Liver resection	2 (1.9)
IVB-V hepatic bisegmentectomy	2 (1.9)
Distal pancreatectomy	1 (0.9)
Resection of Meckel's diverticulum	1 (0.9)
Resection margins ($n = 66$), no. (%)	
R0	63 (95.5)
R1	3 (4.5)
Operative time ($n = 43$)	
Median (range), min	400 (127–750)
Estimated blood loss ($n = 33$)	
Median (range), mL	500 (100–2,760)

PPPD, pylorus preserving pancreaticoduodenectomy; *SMV*, superior mesenteric vein.

Table IV
Postoperative complication, disease recurrence, and overall survival

Characteristic	
Complications ($n = 63$), no. (%)	
Patients with one or more complication	33 (52.4)
Pancreatic fistula	15 (23.8)
Delayed gastric emptying	11 (17.5)
Postoperative infection	4 (6.3)
Abdominal abscess	4 (6.3)
ARDS	2 (3.2)
Surgical site infection	1 (1.6)
Thrombosis	1 (1.6)
Postoperative pneumonia	1 (1.6)
Pancreatico-jejunostomy anastomotic leakage	1 (1.6)
Evisceration	1 (1.6)
Pancreatic leakage	1 (1.6)
Biliary fistula	1 (1.6)
Pelvic abscess	1 (1.6)
Bilateral pulmonary emboli	1 (1.6)
Obstructive jaundice	1 (1.6)
Recurrence	
Recurrent disease ($n = 63$), no. (%)	27 (42.9)
Location of recurrence ($n = 12$), no. (%)	
Liver	5 (50)
Retroperitoneum	2 (20)
Systemic	2 (20)
Peritoneum	1 (10)
Ileum	1 (10)
Overall survival ($n = 103$)	
Median (mo)	168
2 y (%)	75.9
5 y (%)	66.3

ARDS, acute respiratory distress syndrome.

received adjuvant chemotherapy (with chemotherapeutic regimen not specified for 4 patients, 2 patients received fluorouracil (5FU), 2 received capecitabine and oxaliplatin, 1 received folinic acid + fluorouracil + oxaliplatin (FOLFOX)/Bevacizumab). Ten patients who recurred did not receive adjuvant chemotherapy. Treatment of recurrence was specified in 8 of the 27 patients. In the 8 cases for which treatment was specified, only 3 patients underwent surgical intervention with details of their surgical intervention not specified. Thus, the significance of treatment in patients with recurrent disease could not be determined. There were 3 postoperative mortalities. Two of these postoperative mortalities did not report survival time; the third reported a survival time of 7 days.

No cases of neoadjuvant therapy or radiation therapy were reported in our cohort of patients. A total of 54 patients received adjuvant chemotherapy. The majority ($n = 33$, 61.1%) received FOLFOX (Table V). Individual survival data for those receiving adjuvant chemotherapy could only be extrapolated for 33 patients (14 receiving FOLFOX, 14 receiving other chemotherapy regimens, and 5 receiving chemotherapy not specified). There was no significant survival difference between patients who received chemotherapy ($n = 33$, 52.4%) versus patients who received no chemotherapy ($n = 30$, 47.6%). Furthermore, we found no significant difference in survival between those patients who received FOLFOX versus patients who received other chemotherapeutic regimens or between patients who received FOLFOX ($n = 14$) versus patients who received 5FU ($n = 6$). Additionally, we found no survival difference between patients who received FOLFOX ($n = 14$) versus patients who did receive chemotherapy ($n = 30$).

Table V
Chemotherapy

Received chemotherapy, no. (%)	54 (62.1)
FOLFOX	33 (61.1)
5FU	7 (13.0)
Oxaliplatin + capecitibine	3 (5.6)
Capecitibine	3 (5.6)
FOLFOXIRI	1 (1.9)
FOLFIRI	1 (1.9)
NS	5 (9.3)

5FU, fluorouracil; *FOLFOX*, folinic acid + 5FU + oxaliplatin; *FOLFOXIRI*, FOLFOX + irinotecan; *FOLFIRI*, folinic acid + fluorouracil + irinotecan; *NS*, not specified.

Median overall survival was 168 months. Overall survival after resection was 75.9% at 2 years and 66.3% at 5 years (Fig 2, *A*). Six patients survived >10 years.

Survival was significantly greater in patients with no lymph node involvement (stage IIC) compared to those with lymph node involvement (stage IIIC; $P < .001$). Postresection, patients with stage IIC disease had a 2-year survival of 95.5% and 5-year survival of 84.9%. Those with stage IIIC disease had 2-year survival of 61.5% and 5-year survival of 46.4% (Fig 2, *B*). Median overall survival after resection for patients with stage IIC LARCC was not met, while for patients with stage IIIC LARCC was 42.1 months.

Those patients younger than 60 at time of resection had significantly improved survival ($P = .031$) (Fig 2, *C*). Two- and 5-year survival rates for patients <60 years were 88.2% and 70.9%, respectively. Two- and 5-year survival rates were 66.4% and 62.9% for patients ≥60 years (Fig 2, *C*). Median overall survival was not met for patients <60 years old and was 168 months for patients >60 years old. Histopathologic classification did not impact survival ($P = .211$). Median overall survival was 168 months for patients with adenocarcinoma and was not met in patients with mucinous tumors.

Cox regression analysis was performed including the variables of age, sex, stage, margins of resection, histopathology. Cox regression was also performed excluding the variables with the highest number of missing values (margins, chemotherapy, and EBL). In both, lymph node involvement was determined to be the only independently significant variable with a hazard ration of 8.4 ($P = .003$). Although univariable log-rank analysis showed that younger age at time of resection resulted in improved survival (Fig 2, *C*), this is confounded by stage (Table VI).

Discussion

As per AJCC staging criteria, locally advanced colon cancer is defined as T4 tumors (perforation or invasion of adjacent organs and structures) with or without nodal involvement.[5,35] Paramount to the management of locally advanced colorectal cancers (5.5%–16.7% of all colon cancers) is high quality en bloc multivisceral resection in potentially curable cases.[18,36–41] Margin-negative oncologic resection should be followed up with adjuvant chemotherapy.[42] Tumors located in the left colon and rectosigmoid are more likely to present with local invasion than right colon cancers, with the most commonly invaded structures being the peritoneum, abdominal wall, jejunum, and ileum.[43] Although not as common, right colon tumors have been reported to invade the duodenum, pancreas, liver, gall bladder, right kidney, and right adrenal gland.[7,44,45] In our series, the most common site of invasion was the duodenum ($n = 74$) followed by the pancreas ($n = 37$).

Local invasion may indicate aggressive tumor biology, as mucinous and poorly differentiated adenocarcinoma of the colon are associated with a higher incidence of local extension.[46,47] Mucinous carcinoma represents 1.6%–25.4% of all colorectal adenocarcinomas.[48] In our cohort, 11 (11.8%) patients displayed mucinous histologic subtype, whereas 81 patients showed adenocarcinoma NOS. Although the AJCC does not consider mucinous carcinoma to be a significant prognosticator, mucinous carcinoma has been historically regarded as more aggressive than non-mucinous carcinoma.[35,48,49] However, this prognosis may have

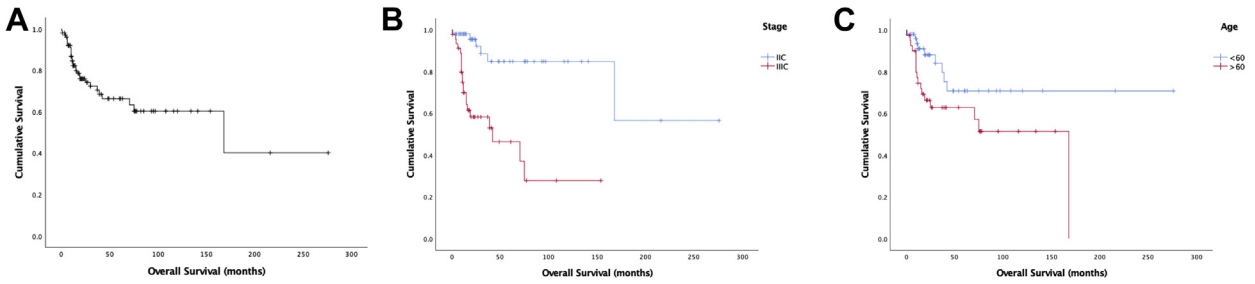

Fig 2. (*A*) Overall survival ($n = 103$). Median survival was 168 months. Survival after resection was 75.9% at 2 years and 66.3% at 5 years. (*B*) Survival in patients with stage IIC ($n = 52$) versus IIIC ($n = 46$) after right hemicolectomy and pancreaticoduodenectomy for locally advanced right colon cancer. Postresection, patients with stage IIC colon cancer had a 2-year survival of 95.5% and 5-year survival of 84.9%. Those with stage IIIC colon cancer with 2-year survival of 61.5% and 5-year survival of 46.4%. Median survival after resection for IIC was not met while for IIIC it was 42.1 months ($P < .001$ on univariable and $P = .003$ on multivariable analysis). (*C*) Survival in patients <60 years ($n = 52$) versus ≥60 ($n = 41$) years after right hemicolectomy and pancreaticoduodenectomy for locally advanced right colon cancer. Two and 5-year survival for patients <60 years was 88.2% and 70.9%, respectively. Two and 5-year survival was 66.4% and 62.9% for patients ≥60 years. Median survival after resection for younger patients <60 years was not met while the median survival in older patients ≥60 years was 168 months ($P = .031$ on univariable).

Table VI
Univariate and multivariable analysis of variables impacting survival after resection

Characteristic	Group	Median survival (mo)	*P* value (univariate)	*P* value (multivariable)
Age	<60 ($n = 52$)	NM	.031	NS
	>60 ($n = 41$)	168		
Sex	Male ($n = 59$)	NM	.125	NS
	Female ($n = 36$)	168		
Stage	IIC ($n = 52$)	NM	<.001	.003
	IIIC ($n = 46$)	42.1		
Margins	R0 ($n = 61$)	168	.905	—
	R1 ($n = 3$)	NM		
Chemotherapy	+ ($n = 33$)	70.4	.968	NS
	− ($n = 30$)	168		
Estimated blood loss	<500 mL ($n = 11$)	NM	.682	—
	>500 mL ($n = 19$)	NM		—
Histopathology	Adenocarcinoma NOS ($n = 81$)	168	.211	—
	Mucinous ($n = 11$)	NM		

—, excluded form multivariable analysis; *NM*, not met; *NS*, not statistically significant.

been related to the higher stage at which mucinous carcinomas present. In our cohort of patients, there was no significant difference in survival between patients with adenocarcinoma NOS versus mucinous. This is consistent with recent literature that reports the prognosis of mucinous carcinoma to be similar to adenocarcinoma NOS when compared stage for stage.[48]

Studies have investigated the importance of complete en bloc resection of locally advanced colon cancer. In these studies, 5-year survival after curative resection ranged from 49%–54%.[5,40,45,50–52] Safety and efficacy of multivisceral resection in the setting of locally advanced colon cancer was investigated by Lehnert et al, where they analyzed 201 patients with colon ($n = 139$) or rectal ($n = 62$) cancer undergoing multivisceral resection. A total of 341 adherent organs were resected for suspected local tumor infiltration. The majority of this cohort of patients presented with primary lesions located in the descending colon, sigmoid colon, and rectum. Thus, the most commonly resected structures include pelvic organs, small bowel excluding the duodenum, and the abdominal wall, while the pancreas and duodenum each accounted for ~5% of resected organs.[51] They reported postoperative complications in 33% of these patients and mortality in 7.5%. R0 resection was found to be the greatest predictor of survival. In addition, 5-year survival after curative resection was 51%. Furthermore, on multivariable analysis, they found EBL <1,000 mL, age <64 years, and Union for International Cancer Control stage of I/II to be a significant prognostic factor improving overall survival in patients for which R0 resection was achieved. The authors concluded that en bloc resection of all adherent organs or structures should be performed.[51] Multivisceral resection in our cohort of patients consisted of PD with a 65.8% 5-year survival after R0 resection, which is superior to outcomes for multivisceral resection for locally advanced colorectal cancer overall as reported by Lenhert et al.

The complexity and morbidity associated with PD and RH for LARCC, as well as paucity of data regarding patient outcomes, have contributed to hesitancy in performing this procedure. Perioperative morbidity and mortality associated with PD for periampullary and pancreatic lesions has been extensively reported in the literature. Morbidity ranges from 40%–58%; with careful patient selection and improvements in surgical and perioperative care, postoperative mortality is now as low as 2%–4% in high volume centers.[6,53–60] Few small studies have specifically looked at perioperative outcomes of patients with LARCC. Paquette et al compared 30-day postoperative outcomes in patients undergoing en bloc PD with RH to patients undergoing colectomy alone for colon cancer in a retrospective study utilizing the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database.[61] They found significantly higher rates of pulmonary complications, blood transfusions, wound complications, and duration of stay in the study group.[61] Mortality was 6.5% in the PD group versus 1.5% in the control group; however, this difference was not found to be significant. Overall complication rate was not reported and long-term outcomes were not investigated in this study.[61] We have found similar postoperative outcomes associated with PD for LARCC as those seen with PD associated with pancreatic cancer, with an overall complication rate of 52.4% and postoperative mortality rate of 2.8% in our cohort of patients.

Lymph node involvement remains the most important prognostic feature in nonmetastatic colon cancer evidenced by survival difference in those with node positive compared to those with node negative disease.[62] Previous studies have reported lymph node involvement in 14%–60% of locally advanced adenocarcinoma.[61,63,64] In a retrospective pooled analysis of cases ($n = 6$) from the author's home institution and literature review ($n = 75$). Li et al also looked at outcomes for patients undergoing RH with PD for LARCC. This study was not included in our analysis due to inability to extract individual patient information from their aggregate data. Furthermore, we were unable to identify the source of patient information. They found positive lymph node status to be an independent predictor of survival.[65] Our cohort of 106 patients were either stage IIC or IIIC with the distinguishing factor between these 2 stages being lymph node involvement. Similarly, we found negative lymph node status to be the only independent variable significantly impacting survival ($P = .003$).

Limitations of this systematic review are largely due to retrospective data collection from heterogeneous case reports and case series. Often, only a fraction of the articles included in our review reported on a specific variable of interest (for example, data pertaining to resection margins was only available for 66 of the 106 patients included in this study). Furthermore, studies were excluded from our analysis when individual patient data could not be extracted from aggregate data. Our search was limited to one database and only included articles written in English, which may contribute to selection bias. Furthermore, cases included in our analysis are subject to publication bias because centers may have preferentially reported cases where this procedure was successfully done with superior outcomes. Further selection bias may be attributed to an unknown number of patients with LARCC who may have been turned away because they were considered poor surgical candidates. Another limitation to this study is the long study time period (1980–2017). Although we have restaged our cohort of patients according to the 8th edition of AJCC, treatment of colorectal cancer patients has changed significantly during this period with the advancement of systemic therapy. Thus, conclusions cannot be drawn about the role of systemic therapy at large based on this small cohort of patients. However, using previously published work as the source of our data provides a unique historical perspective about diagnosis, complications, and outcomes in this patient population and allows for longer follow-up time.

This systematic review concludes that en bloc PD and RH is an effective option for the treatment of locally advanced carcinoma of the right colon. Long-term survival (5-year survival of 66.3%) in our cohort of patients is greater than the 5-year survival reported in the literature after curative resection of locally advanced colon cancer overall. Additionally, we have found negative lymph node status to be the only independent factor significantly improving survival. Furthermore, given the significant complication rate (52.4%), we recommend that these procedures be performed at high volume centers with the experience required to care for these patients.

Conflict of interest

The authors have indicated that they have no conflict of interest regarding the content of this article.

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