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ORIGINAL ARTICLE

A propensity score matched comparison of intracorporeal and extracorporeal techniques for robotic-assisted sigmoidectomy in an enhanced recovery pathway

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Abstract

Intracorporeal options for sigmoid resection have been recently developed but not extensively evaluated. This study was designed to assess outcomes comparing intracorporeal and extracorporeal techniques for robotic-assisted sigmoid resection in an established enhanced recovery pathway. This is a retrospective comparison of intracorporeal and extracorporeal techniques for robotic-assisted sigmoid resection for benign and malignant disease. Operative technique for the newer intracorporeal innovation is described in detail. Propensity score matching was performed using patient characteristics as predictors in the propensity score model. 169 cases met inclusion criteria. After propensity score matching, 114 cases were available for analysis (intracorporeal 57, extracorporeal 57). Almost 90% were for diverticulitis in each group. There were significantly fewer conversions in the intracorporeal group when compared to the extracorporeal group (5.26% vs. 19.3%, $P=0.029$). Operative time was significantly longer in the intracorporeal group (193.33 vs. 159.89 min, $P<0.001$). There was no significant difference between groups for time to flatus and bowel movements, hospital length of stay, postoperative 30-day complications, and readmission rates. There were significantly fewer extraction site hernias in the intracorporeal group (0 vs. 6 (10.53%), $P=0.027$) likely because there were fewer midline extraction sites (8.77% vs. 38.6%, $P<0.001$). When compared to extracorporeal techniques for robotic sigmoid resection in an enhanced recovery pathway, the intracorporeal approach is safe and associated with fewer conversions, fewer extraction site hernias, and longer operating times. As adoption of the intracorporeal approach continues to increase, further analysis of this technique in larger studies may be warranted.

Keywords Intracorporeal anastomosis · Robotic · Colorectal · Minimally invasive

Introduction

Recent studies suggest that intracorporeal anastomotic techniques (IA) may have outcome advantages when compared to the extracorporeal approach (EA) for right colectomy for benign and malignant diseases of the colon [1–6]. Time to gastrointestinal activity may be shorter for the IA approach, because there are fewer operative challenges with less operative trauma getting the transverse colon and mesentery to a small midline specimen extraction site as can occur with the EA approach. In addition, extraction site incisional hernias have been reported to be less for the IA approach, because the specimen is removed through an off-midline extraction site incision where hernia rates are considerably less than in the EA midline extraction site location [6–9].

The IA approach includes a long colotomy for anvil placement thereby exposing the peritoneal cavity to bacteria-laden mucosa, increasing the risk for infectious and other complications. This study is one of the first to consider the safety and efficacy of the IA technique for sigmoid resection and to determine if there are outcome advantages

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or disadvantages within an established enhanced recovery pathway colorectal surgery service.

Methods

Data source

This study is a single institution retrospective analysis of de-identified perioperative data for consecutive cases of robotic-assisted sigmoid resection for benign and malignant diseases between February 24, 2012, and November 15, 2017. The IA technique was used routinely starting in March, 2016. Patients who had sigmoid resection with the IA technique after March, 2016 were compared to patients treated with the EA technique prior to this date. Data were retrieved by standardized review of hospital and office electronic medical records using RED CAP® data collection forms. Operative approach for colorectal operations included identification of the type of anastomosis and converted cases through detailed surveillance of the operative report dictated by the surgeon. This study was approved by the Institutional Review Board at St Joseph Mercy Hospital Ann Arbor.

Surgical technique

Study patients underwent elective robotic-assisted sigmoid resection with selective splenic flexure mobilization for a tension-free anastomosis. The IA group had complete detachment of the colon and mesentery from retroperitoneal structures, division of the inferior mesenteric vessels, robotic division of soft and pliable descending colon, and robotic division of the upper rectum. The specimen was stored on the right side of the abdomen until retrieval through the extraction site incision following a robotic circular stapled anastomosis. The stapler anvil was placed in the abdomen through a Pfannenstiel incision without de-docking the robot. This Pfannenstiel incision served as the specimen extraction site following completion of the anastomosis. Using robotic techniques, a long colotomy was made on the specimen side, and a small colotomy proximal to the proposed point of transection of the descending colon. The anvil was placed through the long colotomy and the shaft routed through the small colotomy. The descending colon was then divided with the robotic stapler leaving the long colotomy with the specimen and leaving the anvil in the descending colon for the anastomosis. The anastomosis was then constructed side-of-the-colon to end-of-the-rectum, coordinated with robotic vision and robotic manipulation of the anvil, and with the perineal operator inserting the circular stapler per anum.

The EA technique was characterized by robotic mobilization of the colon and mesentery, division of the inferior mesenteric vessels, robotic division of the upper rectum, and then delivery of the proximal divided end through an extraction site incision. Further division of remaining mesentery (when necessary) and resection of the specimen and placement of the anvil in the descending colon were then done by standard open techniques typically conducted for extracorporeal minimally invasive procedures. The colon with the anvil was then returned to the abdominal cavity and pneumoperitoneum reinstituted, and the anastomosis was done with laparoscopic vision and laparoscopic instruments.

Immunofluorescence for identification of the ureter and for determining colon and rectum viability was used for both groups. Because both techniques are characterized by an "intracorporeal anastomosis"—one robotic and one laparoscopic—the study groups are more accurately referred to as intracorporeal and extracorporeal techniques that include an intracorporeal anastomosis. These techniques were derived from the National Colon and Rectal Surgery Fellowship Robotic Training Course. The senior author was one of three surgeons who developed and implemented the course in 2011.

Both da Vinci Si® and Xi® systems were used in this study and not controlled for in the statistical analysis.

Outcome and explanatory variables

Baseline patient characteristics included patient demographics, general health factors, patient comorbidities, and previous abdominal surgery. Operative characteristics retrieved for comparison included indication for surgery (diverticular disease, malignant or benign neoplasia), operative time (skin incision to skin closure), incision size, and specimen extraction site (midline, off-midline, Pfannenstiel). Incision size was measured at the time of skin closure.

Postoperative outcomes data for this study included time to first flatus, time to first bowel movement, mean number of postoperative complications, and individual postoperative complications—ileus, surgical site infection, sepsis, anastomotic leak, Clostridium difficile infection, gastrointestinal hemorrhage, acute kidney injury, dehydration, urinary retention, urinary tract infection, congestive heart failure, pneumonia, deep venous thrombosis, pulmonary embolus, discharge destination, readmission, and reoperation.

Statistical analysis

Summary statistics (mean and SD for interval variables, *N* and % for categorical variables) were calculated for the perioperative variables included in the study. Statistical significance was tested using *t* test for interval variables and Chi square or Fisher exact tests for categorical variables. Propensity score matching was performed using age, BMI, pre-existing comorbidities, prior abdominal procedures, and tobacco and alcohol use as predictors in the propensity score models. Table 1 displays variables used in the logistic regression model that estimated the propensity scores. The matching algorithm was nearest neighbor with a caliper 0.2 standard deviations. Summary statistics and inferential tests were then repeated on the propensity score matched subsample.

Results

A total of 169 robotic-assisted sigmoid resections met the inclusion criteria. After propensity score matching, 114 cases were available for analysis (IA $N=57$, EA $N=57$). There were no significant differences in any patient characteristics between the groups both before and after propensity score matching (Table 1). Operative characteristics are shown in Table 2. Almost 90% of cases were for diverticular disease in each group (IA 85.96% vs. EA 91.23%). The IA diverticular disease group included 26 (45.61%) cases with pelvic abscesses, 10 of whom had colovesical and/or colovaginal fistulas, while the EA diverticular disease group had 21 (36.85%) cases with pelvic abscesses, 6 of whom had colovesical and/or colovaginal fistulas.

There were significantly fewer conversions in the IA group compared to the EA group (5.26% vs. 19.3%, $P=0.029$). Of the three conversions in the IA group, all were converted to open. Of the 11 conversions in the EA group, 6 were converted to open and 5 were converted to and completed by the laparoscopic hand assist (HA) approach through a lower midline incision. Of the 12 patients in the study converted to open, 9 were for pelvic abscess, 1 for intraoperative bleeding, 1 for morbid obesity, and 1 for colonic ischemia requiring further resection. Of the three

Table 1 Patient characteristics

Variable	Label	Unadjusted			Propensity score matched		
		Intracorporeal (*N*=60)	Extracorporeal (*N*=109)	*P* value	Intracorporeal (*N*=57)	Extracorporeal (*N*=57)	*P* value
Age, mean (SD)		62.55 (9.849)	60.787 (10.92)	0.301	62.193 (9.934)	63 (9.98)	0.666
Sex, *N* (%)	Female	26 (43.33%)	52 (47.71%)	0.701	24 (42.11%)	30 (52.63%)	0.348
Race, *N* (%)	White	59 (98.33%)	100 (91.74%)	0.099	56 (98.25%)	51 (89.47%)	0.113
	Non-white	1 (1.67%)	9 (8.26%)		1 (1.75%)	6 (10.53%)	
BMI, mean (SD)		28.4 (5.878)	29.339 (5.52)	0.302	28.632 (5.939)	29.123 (4.954)	0.632
Number of comorbidities, mean (SD)		1.5 (1.295)	1.505 (1.331)	0.983	1.509 (1.325)	1.544 (1.351)	0.889
ASA class, *N* (%)	ASA class 1 or 2	38 (63.33%)	73 (66.97%)	0.758	36 (63.16%)	36 (63.16%)	> 0.999
	ASA class 3 or 4	22 (36.67%)	36 (33.03%)		21 (36.84%)	21 (36.84%)	
Tobacco, *N* (%)		16 (26.67%)	30 (27.52%)	> 0.999	16 (28.07%)	16 (28.07%)	> 0.999
Alcohol, *N* (%)		0 (0%)	4 (3.67%)	0.298	0 (0%)	2 (3.51%)	0.496
Opioid, *N* (%)		0 (0%)	2 (1.83%)	0.539	0 (0%)	1 (1.75%)	> 0.999
Hx apnea, *N* (%)		9 (15%)	19 (17.43%)	0.849	9 (15.79%)	9 (15.79%)	> 0.999
Hx arrhythmia, *N* (%)		2 (3.33%)	12 (11.01%)	0.142	2 (3.51%)	1 (1.75%)	> 0.999
Hx CAD, *N* (%)		8 (13.33%)	9 (8.26%)	0.434	7 (12.28%)	6 (10.53%)	> 0.999
Hx CHF, *N* (%)		2 (3.33%)	2 (1.83%)	0.616	2 (3.51%)	1 (1.75%)	> 0.999
Hx cirrhosis, *N* (%)		1 (1.67%)	0 (0%)	0.355	1 (1.75%)	0 (0%)	> 0.999
Hx COPD, *N* (%)		4 (6.67%)	7 (6.42%)	> 0.999	4 (7.02%)	7 (12.28%)	0.526
Hx diabetes, *N* (%)		5 (8.33%)	13 (11.93%)	0.643	5 (8.77%)	8 (14.04%)	0.556
Hx DVT/PE, *N* (%)		3 (5%)	2 (1.83%)	0.348	2 (3.51%)	2 (3.51%)	> 0.999
Hx hypertension, *N* (%)		30 (50%)	52 (47.71%)	0.901	28 (49.12%)	24 (42.11%)	0.573
Hx previous abdominal surgery, *N* (%)		23 (38.33%)	44 (40.37%)	0.925	23 (40.35%)	28 (49.12%)	0.451
Hx renal disease, *N* (%)		3 (5%)	4 (3.67%)	0.7	3 (5.26%)	2 (3.51%)	> 0.999

P values for categorical outcomes from Chi square and Fisher exact tests. *P* values for continuous outcomes from independent samples *t* test

CAD coronary artery disease, *CHF* congestive heart failure, *COPD* chronic obstructive pulmonary disease, *DVT/PE* deep vein thrombosis/pulmonary embolism

Table 2 Operative characteristics

Variable	Label	Unadjusted			Propensity score matched		
		Intracorporeal	Extracorporeal	P value[a]	Intracorporeal	Extracorporeal	P value[a]
Indication for surgery, N (%)	Benign or malignant neoplasia or other	8 (13.33%)	20 (18.35%)	0.533	8 (14.04%)	5 (8.77%)	0.556
	Diverticulitis	52 (86.67%)	89 (81.65%)		49 (85.96%)	52 (91.23%)	
	Diverticulitis without abscess	24 (40%)	56 (51.38%)	0.137	23 (40.35%)	31 (54.39%)	0.345
	Diverticulitis + pelvic abscess	18 (30%)	23 (21.1%)		16 (28.07%)	15 (26.32%)	
	Diverticulitis + pelvic abscess + colovesical/colovaginal fistula	10 (16.67%)	10 (9.17%)		10 (17.54%)	6 (10.53%)	
Conversion, N (%)	No conversion	57 (95%)	93 (85.32%)	0.082	54 (94.74%)	46 (80.7%)	0.029
Conversion type, N (%)	Conversion to open	3 (5%)	9 (8.26%)		3 (5.26%)	6 (10.53%)	
	Conversion to hand assist	0 (0%)	7 (6.42%)		0 (0%)	5 (8.77%)	
Operative time, mean (SD)		193.16 (31.32)	160.16 (27.509)	< 0.001	193.33 (31.338)	159.89 (32.033)	< 0.001
Incision size in cm, mean (SD)		5.544 (0.974)	5.333 (1.338)	0.304	5.62 (0.931)	5.38 (1.427)	0.315
Extraction site, N (%)	Midline	5 (8.33%)	36 (33.03%)	< 0.001	5 (8.77%)	22 (38.6%)	< 0.001
	Off-midline	1 (1.67%)	2 (1.83%)		1 (1.75%)	1 (1.75%)	
	Pfannenstiel	54 (90%)	71 (65.14%)		51 (89.47%)	34 (59.65%)	
Splenic flexure		30 (50%)	40 (36.7%)	0.129	29 (50.88%)	21 (36.84%)	0.186

Variable	Label	Splenic flexure = no (N = 99)	Splenic flexure = yes (N = 70)	P value[b]
Xi versus SI	Xi	8 (8.08%)	13 (18.57%)	0.072
	Si	91 (91.92%)	57 (81.43%)	
Diverticulitis	Diverticulitis or diverticulitis + pelvic abscess	70 (88.61%)	51 (82.26%)	0.407
	Diverticulitis + pelvic abscess + colovesical/colovaginal fistula	9 (11.39%)	11 (17.74%)	
BMI	≤ 35	85 (85.46%)	66 (94.29%)	0.135
	> 35	14 (14.14%)	4 (5.71%)	

[a]*P* values for categorical outcomes from Chi square and Fisher exact tests. *P* values for continuous outcomes from independent samples *t* test. Incision size, and operative time exclude converted cases

[b]*P* values from Chi square test. Diverticulitis comparison excludes non-diverticulitis cases

cases converted to the laparoscopic HA approach, all three were for pelvic abscess.

Operative time was significantly longer in the IA group when compared to the EA group (193.33 vs. 159.89 min, $P < 0.001$). Incision size was not significantly different between groups ($P = 0.315$). There were significantly more midline extraction site incisions in the EA group when compared to the IA group both in the unadjusted comparison (33.03% vs. 8.33%, $P < 0.001$) and after propensity score matching (38.6% vs. 8.77%, $P < 0.001$).

There was no significant difference in splenic flexure mobilization between IA and EA groups both before and after propensity score matching ($P = 0.186$). There was a trend toward more splenic flexure mobilization with the Xi compared to the Si platform but this did not reach statistical significance ($P = 0.072$). There was no significant difference in splenic flexure mobilization with respect to complicated diverticulitis and BMI.

Postoperative outcomes are shown in Table 3. Time to first flatus ($P = 0.658$) and time to first bowel movement ($P = 0.546$) were not significantly different between IA and EA groups. Hospital LOS was not significantly different between groups both in the unadjusted analysis (IA 2.91 days vs. EA 3.98 days, $P = 0.062$) and after propensity score matching (IA 2.94 days vs. EA 3.98 days, $P = 0.184$). There was no significant difference between groups for any of the 30-day postoperative complications, including sepsis, SSI, and anastomotic leaks, discharge destination, and readmission rates. There were significantly fewer extraction site hernias in the IA group when compared to the EA group (0 (0%)

Table 3 Postoperative outcomes

Variable	Unadjusted			Propensity score matched		
	Intracorporeal (*N* = 60)	Extracorporeal (*N* = 109)	*P* value	Intracorporeal (*N* = 57)	Extracorporeal (*N* = 57)	*P* value
Time to first flatus, mean (SD)	35.618 (22.413)	35.312 (17.736)	0.928	35.01 (22.584)	37 (20.792)	0.658
Time to first bowel movement, mean (SD)	36.888 (22.962)	37.789 (20.15)	0.828	36.203 (23.266)	39.375 (22.567)	0.546
LOS, mean (SD)	2.914 (1.863)	3.982 (4.952)	0.062	2.935 (1.597)	3.981 (5.09)	0.184
Number of complications, mean (SD)	0.617 (1.166)	0.706 (1.157)	0.631	0.579 (1.101)	0.737 (1.126)	0.451
Ileus, *N* (%)	2 (3.33%)	5 (4.59%)	> 0.999	1 (1.75%)	4 (7.02%)	0.364
Any SSI, *N* (%)	1 (1.67%)	8 (7.34%)	0.161	1 (1.75%)	7 (12.28%)	0.061
Sepsis, *N* (%)	1 (1.67%)	1 (0.92%)	> 0.999	1 (1.75%)	0 (0%)	> 0.999
Anastomotic leak, *N* (%)	2 (3.33%)	0 (0%)	0.125	2 (3.51%)	0 (0%)	0.496
C. diff, *N* (%)	0 (0%)	2 (1.83%)	0.539	0 (0%)	0 (0%)	NA
GI bleeding, *N* (%)	4 (6.67%)	4 (3.67%)	0.456	3 (5.26%)	2 (3.51%)	> 0.999
AKI, *N* (%)	2 (3.33%)	1 (0.92%)	0.287	2 (3.51%)	0 (0%)	0.496
Dehydration, *N* (%)	1 (1.67%)	1 (0.92%)	> 0.999	0 (0%)	0 (0%)	NA
Urinary retention, *N* (%)	4 (6.67%)	2 (1.83%)	0.187	4 (7.02%)	0 (0%)	0.118
UTI, *N* (%)	1 (1.67%)	7 (6.42%)	0.262	1 (1.75%)	5 (8.77%)	0.206
CHF, *N* (%)	0 (0%)	1 (0.92%)	> 0.999	0 (0%)	1 (1.75%)	> 0.999
Pneumonia, *N* (%)	0 (0%)	2 (1.83%)	0.539	0 (0%)	1 (1.75%)	> 0.999
DVT, *N* (%)	1 (1.67%)	1 (0.92%)	> 0.999	1 (1.75%)	0 (0%)	> 0.999
PE, *N* (%)	0 (0%)	1 (0.92%)	> 0.999	0 (0%)	0 (0%)	NA
Discharged not to home, *N* (%)	1 (1.67%)	2 (1.83%)	> 0.999	1 (1.75%)	1 (1.75%)	> 0.999
Readmission, *N* (%)	5 (8.33%)	8 (7.34%)	0.773	5 (8.77%)	5 (8.77%)	> 0.999
Reoperation, *N* (%)	1 (1.67%)	2 (1.83%)	> 0.999	1 (1.75%)	1 (1.75%)	> 0.999
Hernia, *N* (%)	0 (0%)	9 (8.26%)	0.027	0 (0%)	6 (10.53%)	0.027

No recorded cases of mortality. *P* values for categorical outcomes from Chi square and Fisher exact tests. *P* values for continuous outcomes from independent samples *t* test. Hospital LOS calculations exclude converted cases

LOS hospital length of stay, *AKI* acute kidney infection, *SSI* surgical site infections, *DVT* deep vein thrombosis, *PE* pulmonary embolism, *UTI* urinary tract infection

vs. 6 (10.53%), $P = 0.027$), and significantly fewer extraction site hernias in the off-midline/Pfannenstiel extraction site location when compared to the midline extraction site location (0 (0%) vs. 6 (22.22%), $P < 0.001$).

Discussion

This propensity score matched comparison of IA and EA approaches for robotic sigmoid resection for benign and malignant disease in an enhanced recovery pathway reveals that there are outcomes advantages to the IA technique that include significantly fewer conversions to open and significantly fewer extraction site hernias, likely because there are fewer midline incisions associated with the IA technique. There was no increase in surgical site infections and sepsis associated with intracorporeal anvil placement in the IA group. In contrast to studies comparing IA and EA techniques for right colectomy, there was no significant difference in time to gastrointestinal recovery, hospital LOS, and 30-day complications between IA and EA groups [1, 2, 5, 6, 10]. Operative times were significantly longer for the IA approach when compared to the EA technique.

With increasing adoption of the IA technique for right colectomy, we hypothesized that the outcomes advantages may be extended to other colorectal operations. Though the time to gastrointestinal recovery and hospital LOS advantages for IA right colectomy were not apparent for IA sigmoid resection in this study, the overall outcomes were favorable and the IA technique warrants further analysis in larger studies. Extraction site hernia rates are favorable at off-midline sites for sigmoid resections as they are for right colectomy. The significantly higher midline extraction site incision rate for the EA group when compared to the IA group was an unexpected finding. For some EA surgeons, a lower midline incision extraction site incision is made for patients who are obese and for those with complicated diverticulitis in anticipation of possible conversion. In this study, 11 of the 22 midline extraction site incisions were for conversions, while the others did not need conversion.

While our study reveals a significant difference in conversion to open for the IA group when compared to the EA group, we know of no other similar studies of patients undergoing sigmoid resection for comparison. Studies addressing conversion differences between IA and EA techniques for right colectomy reveal inconsistent results with some showing fewer conversions for the IA group when compared to the EA group and others revealing no significant difference [11–13]. Patients who present with diverticular abscesses or fistulas may be at a higher risk for conversion. Fifteen (78.9%) of the 19 conversions in this study were for diverticular abscess with or without fistula. Six of these conversions for pelvic abscess were to laparoscopic HA rather than open, thereby preserving a minimally invasive approach in those cases. Conversion to HA may be a viable option for some patients with complicated diverticular disease when the operation cannot be completed by the robotic approach. There was only one conversion for obesity in the IA group and none in the EA group though studies suggest that the IA approach may be the only minimally invasive option without conversion for some patients with high BMI, short and thick mesentery, and thick abdominal wall [14].

The EA technique is characterized by bringing a diseased segment of colon to an extraction site incision where resection of the specimen and placement of the anvil is done by standard open techniques. This may be challenging in obese individuals and may result in the need to use a midline incision and possibly lengthen the incision. In contrast, the incision extraction site and length for the IA approach is limited only by the width of the specimen. We excluded converted cases for the incision length variable and there was no difference in incision length between IA and EA groups in our study. Others have confirmed this finding [13, 15].

The significant difference in incisional hernias between midline and off-midline specimen extraction sites in our study is consistent with other studies [7–9]. In an analysis of 480 laparoscopic colorectal procedures, Samia et al. found significantly more incisional hernias in midline extraction sites when compared to off-midline sites (midline 8.9% vs. muscle-splitting 2.3%, Pfannenstiel 3.8%, ostomy site 4.8%, $P = 0.008$) [7]. In a single institution analysis of multiport and single incision robotic colorectal surgeries, Harr et al. found a significantly higher hernia rate for midline extraction sites when compared to muscle-splitting incisions (12.4% vs. 0.68%, $P < 0.0001$) [8]. A review of 276 patients undergoing laparoscopic and robotic right colectomy for neoplasia found that 20% of incisional hernias are identified within 1 year at the postoperative visit follow-up physical examination or by follow-up CT imaging [9]. This study suggests that the incisional hernia rate in our study would likely be higher with longer follow-up. Incisional hernias can cause considerable long-term morbidity related to complex mesh repairs and recurrence and so minimally invasive options that allow off-midline extraction sites warrant consideration. The results of our study resulted in a practice change to using off-midline extraction site incisions for cases converted to HA and using midline incisions only for conversion to open cases when there is a need to access multiple quadrants or there is concern about adequate visualization after conversion seems likely.

Operating time was significantly longer in the IA group when compared to the EA group. Other studies comparing IA and EA techniques for right colectomy are inconsistent with some confirming longer times for the IA group and others showing no difference [3, 13–15]. Operative time has been shown to improve with surgeon's experience [16–18]. However, the longer operating times in this study were in the IA group that consisted of patients in the latter part of the study period when surgeons were most experienced. Though a cost comparison was not included in this study, other studies have shown that operating time significantly contributes to cost when comparing MIS modalities [19]. Operating time will likely be a variable in future cost effectiveness comparisons.

Hospital LOS was not significantly different between IA and EA groups in our study. Studies comparing IA and EA techniques for sigmoid resection are lacking, and laparoscopic and robotic right colectomy studies show mixed results with some revealing a shorter hospital LOS for IA and others showing no significant difference [1, 2, 5, 6, 10, 13]. Other studies are confounded by factors that can impact LOS such as surgeon and hospital variations in preadmission education, opioid use, early feeding, early mobilization, and other key components of enhanced recovery pathways [20, 21]. Our study patients had equal access to our comprehensive enhanced recovery pathway. If there was a significant difference between IA and EA groups with respect to time to gastrointestinal recovery and hospital LOS in our study, it would likely be related to factors outside of enhanced recovery. We hypothesized that traction on the colon and mesentery to the EA group extraction site incision with risk of mesenteric bleeding would result in a longer time to gastrointestinal recovery, ileus, and longer hospital LOS in this group when compared to the IA group. This IA advantage that has been revealed in other studies for right colectomies was not confirmed in our study comparing IA and EA for sigmoid resection [5, 6, 10, 13]. It may be that the EA challenges with the transverse colon reaching the midline extraction site for the right colectomy are not as relevant as the descending colon reach for sigmoid resection extraction sites.

This study has limitations inherent to any retrospective comparison. It is a single institution analysis and may not be generalizable to other surgeons in settings with different minimally invasive barriers. We recognize that some surgeons choose off-midline extraction sites even when the risk for conversion is increased and some routinely mobilize the splenic flexure. Diverticulitis is a common operative diagnosis in our patient population and may be less common in the university setting. The EA approach was for cases earlier in the study period. However, the senior author had performed 139 robotic colorectal resections prior to the start of this study. All cases done by the senior author are currently done with the IA approach and so IA could be a proxy for a surgeon further along in the learning curve. Surgeon experience did not appear to contribute to a difference in results, however, and the longer operating times for the IA group were later in the study period. Some of the outcomes like splenic flexure mobilization may be underpowered by this single institution sample size.

Both IA and EA groups had an intracorporeal anastomosis, the latter after resection of the specimen and anvil placement using standard open techniques through the extraction site incision. This study is a comparison of IA and EA techniques that include an intracorporeal anastomosis, rather than a comparison of the anastomosis alone. The IA technique includes takedown of the mesentery and vessels, division of the descending colon and upper rectum, placing an anvil through an intracorporeal colotomy, and performing the anastomosis prior to specimen extraction. These IA maneuvers did not result in an increase in surgical infections and sepsis and outcomes were favorable. We have adopted IA as the preferred technique for sigmoid and low anterior resections because it precludes stretching and negotiating the colon and mesentery through a small extraction site incision with difficult visualization and because sometimes the only option for a morbidly obese patient is an IA approach.

Conclusion

This single institution comparison of intracorporeal and extracorporeal techniques for robotic sigmoid resection for patients on a dedicated enhanced recovery pathway colorectal surgery service reveals that the IA technique is safe for benign and malignant diseases. Conversion rates and extraction site hernias are significantly less for the intracorporeal approach. As minimally invasive options and the intracorporeal technique continue to evolve, larger studies to confirm or refute these findings may be warranted.

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Compliance with ethical standards

Conflict of interest Dr. Al Natour has nothing to disclose. Dr. Obias is a consultant for Intuitive Surgical, Inc. Dr. Albright has nothing to disclose. Dr. Wu has nothing to disclose. Ms. Ferraro has nothing to disclose. Dr. Akram has nothing to disclose. Dr. Cleary is an educational speaker and has received honoraria from Intuitive Surgical, Inc.

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