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ORIGINAL ARTICLE

Robotic-assisted ileocolic resection for Crohn's disease: outcomes from an early national experience

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Abstract
Crohn's disease is an incurable inflammatory disorder that can affect the entire gastrointestinal tract. While medical management is considered first-line treatment, approximately 70–90% of patients with Crohn's disease will require at least one surgical intervention during the course of their lifetimes. Traditionally, abdominal surgery for Crohn's disease has been performed via an open approach with an increasing adoption of minimally invasive techniques. The aim of this study was to evaluate and compare postoperative outcomes from an initial national experience with robotic-assisted ileocolic resection for Crohn's disease. Patients who underwent elective ileocolic resection for Crohn's disease by robotic-assisted or open approaches from 2011 to Q3 2015 were identified using ICD-9 codes from the Premier Healthcare Database. Propensity-score matching (1:1) was performed using age, gender, race, Charlson index score, and year of surgery to form comparable cohorts in order to compare the robotic-assisted and open groups. 3641 patients underwent elective ileocolic resection for Crohn's disease during the study period (1910 [52.5%] open and 109 [3%] robotic-assisted). Post-matched comparison of cohorts ($n = 108$ per cohort) showed that robotic-assisted cases were longer by a mean of 60 min ($p < 0.0001$), had shorter length of hospital stay by a median of 2 days ($p < 0.001$) and a lower 30-day complication rate (24% vs. 38%; $p = 0.039$). This national database assessment of patients undergoing elective ileocolic resection for Crohn's disease demonstrated that a robotic-assisted approach was associated with longer operative times, shorter length of hospital stay and lower 30-day complication rates compared to open approach.

Keywords Crohn's disease · Ileocolic resection · Robotic-assisted · Minimally invasive surgery · Inflammatory bowel disease

Introduction

Crohn's disease (CD) is an incurable inflammatory disorder that can affect the entire gastrointestinal tract. While medical management is considered first-line treatment, an estimated 70–90% of patients with CD will require at least one surgical intervention during the course of their lifetimes [1] and an estimated 33–82% of patients will require multiple surgeries [2]. Traditionally, surgery has been performed via an open approach (OA) with increasing adoption of minimally invasive surgery (MIS), given its associated benefits of shorter duration of postoperative ileus and length of hospital stay [3]. Several observational reports and three meta-analyses have demonstrated successful application of laparoscopy in the hands of experienced laparoscopic surgeons, and a growing interest in MIS management of Crohn's disease despite technical challenges [4–9].

As an MIS approach, the robotic-assisted approach (RA) provides technical advantages, including three-dimensional visualization, a stable camera platform, wristed instruments, and immunofluorescence capability [10]. In consideration of the interest in minimally invasive management of CD, we sought to evaluate and compare outcomes of patients with CD undergoing elective ileocolic resection using robotic-assisted and open approaches.

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Patients and methods

Data sources and study sample

Patients undergoing elective open and robotic-assisted ileocolic resection for CD were identified using ICD-9-CM codes from the Premier Healthcare Database [11]. This database provides administrative data for payers from more than 700 academic and community hospitals in various geographical locations in the United States and represents 20% of all inpatient hospital discharges. The Premier database is aggregated, de-identified, and compliant with the Health Insurance Portability and Accountability Act; thus, our study did not require institutional review board approval.

Inclusion criteria were age ≥ 18 years and elective robotic-assisted or open ileocolic resection for Crohn's disease from January 1, 2011 through September 30, 2015. Exclusion criteria included emergency operations, cases with operating room times of ≤ 1 h or ≥ 8 h and cases with hospital length of stay fewer than 2 days or more than 30 days. International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) procedure codes and current procedure terminology (CPT) codes were used to identify the surgical approaches. ICD-9-CM codes were used to identify complications and conversion to an open approach.

Analyzed data included baseline patient characteristics (age, gender, race, Charlson Comorbidity Index [12], and year of surgery), hospital characteristics (payor type, census region, urban or rural location, teaching status, number of beds), provider specialty (general or colorectal surgery), and perioperative outcomes (operating room time, conversion to open, blood transfusion, hospital length of stay, discharge status, and 30-day complications).

Statistical methods

In an effort to offset potential for selection bias between surgical approaches (open and robotic-assisted), we performed propensity-score matching and used the nearest neighbor approach [13]. Cases were matched one-to-one with a caliper size of 0.01 and resulted in 108 patients in each matched cohort. Hospital characteristics of the two cohorts were comparable prior to matching; consequently, five baseline characteristics were used for the propensity-score matching to create comparable cohorts for analysis: patient age, gender, race, Charlson index score, and year of surgery.

Univariate analysis was performed before and after matching: Student's *t* test was used for continuous variables and Chi-square test or Fisher's exact test for categorical variables. Sample selection and creation of analytic variables were performed using Instant Health Data (IHD) platform (Boston Health Economics, Inc., Waltham, MA). All tests were two-sided, with statistical significance set at $p < 0.05$. Statistical analyses were undertaken with R-statistical software, version 3.2.1 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the 3641 patients who underwent elective ileocolic resection for CD during the study period, 1910 (52.5%) were performed by OA and 109 (3.0%) were performed by RA. After propensity-score matching, the population in each cohort was 108.

Unmatched patient characteristics are presented in Table 1 and show statistically significant differences in age, gender, and race between the robotic-assisted and open cohorts. The Charlson Comorbidity Index was comparable between the unmatched cohorts.

Unmatched payor, hospital, and provider characteristics as well as year of surgery are listed in Table 2. The majority of payors in each group were commercial (RA 54.1%, OA 61.0%); hospitals were primarily urban (RA 97.2%, OA 93.4%) and in the South (RA 56.0%, OA 47.3%) with hospitals evenly divided between academic and community hospitals that were large (≥ 500 beds). The majority of operations were performed by general surgeons (RA 58.7%, OA 71.8%).

Propensity-score matched group

Baseline demographics and characteristics after propensity-score matching are presented in Table 1. The majority of patients were in the 18- to 34-year-old category (RA 38.9%, OA 37.0%), and were female (RA 65.7%, OA 63.9%) and White or Caucasian (RA 78.7%, OA 81.5%). Likewise, the Charlson Comorbidity Index was comparable between cohorts [RA 0.31 ± 0.63, OA 0.31 ± 0.68 ($p = 0.9145$)].

Payor, hospital and provider characteristics as well as distribution of operations by year were comparable between the robotic-assisted and open cohorts (Table 2). Most payors were commercial (RA 53.7%, OA 62.0%), and procedures were performed primarily in large (≥ 500 beds) hospitals (RA 47.2%, OA 49.1%). Most of the hospitals were urban (RA 97.2%, OA 93.5%) and were in the South (RA 55.6%, OA 43.5%). The teaching status of the hospitals was evenly distributed among academic (RA 46.3%, OA 54.6%) and community (RA 53.7%, OA

Table 1 Patient demographics and baseline characteristics prior to and after propensity-score matching (PSM)

Characteristic	Prior to PSM			After PSM		
	Robotic-assisted ($N=109$)	Open ($N=1910$)	p value	Robotic-assisted ($N=108$)	Open ($N=108$)	p value
Mean age, years (mean ± SD)	43.2 (16.5)	46.5 (16.0)	0.0268	43.1 (16.5)	43.8 (18.2)	0.8728
Age categories, *n* (%)			0.069			0.9034
18–34 years	42 (38.5)	518 (27.1)		42 (38.9)	40 (37.0)	
35–44 years	20 (18.3)	372 (19.5)		20 (18.5)	22 (20.4)	
45–64 years	32 (29.4)	721 (37.5)		31 (28.7)	28 (25.9)	
> 65 years	15 (13.8)	299 (15.7)		15 (13.9)	18 (16.7)	
Gender, *n* (%)			0.0017			0.8867
Female	72 (66.1)	1016 (53.2)				
Male	37 (33.9)	894 (46.8)				
Race, *n* (%)			0.0005			0.8546
Black or African American	10 (9.2)	153 (8.0)		10 (9.3)	8 (7.4)	
White or Caucasian	85 (78.0)	1528 (80.0)		85 (78.7)	88 (81.5)	
Hispanic	1 (0.92)					
Other	13 (11.9)	228 (11.9)		13 (12.0)	12 (11.1)	
Charlson Comorbidity Index (mean ± SD)	0.30 (0.63)	0.40 (1)	0.9859	0.31 (0.63)	0.31 (0.68)	0.9145

PSM propensity-score matching, *SD* standard deviation of the mean

45.4%) medical centers ($p=0.9983$). In both cohorts, general surgeons performed most of the operations (RA 58.3%, OA 69.4%).

Clinical outcomes and perioperative complications after propensity-score matching are listed in Tables 3 and 4, respectively. The operating room time was significantly longer for the RA cohort [RA 240.7 ± 79.7 min, OA 181.0 ± 84.5 min ($p<0.0001$)] with a mean difference of approximately 59 min. Of the RA procedures, 10 (9.3%) were converted to laparotomy. Length of hospital stay was significantly shorter for the RA cohort than for the OA cohort by a median of 2 days [RA median, 5 days; OA median, 7 days ($p<0.0001$)] and, in both cohorts, most patients were discharged directly to home. No mortalities were reported during the hospitalization period.

Rates of intraoperative and postoperative complications were comparable between cohorts ($p=1.000$ and $p=0.1671$, respectively). However, the 30-day complication rates were significantly less for the RA cohort (24.1%) than for the OA cohort (38.0%) ($p=0.0395$). Differences in rates of postoperative ileus and intestinal obstruction were not significantly different between cohorts ($p=0.1303$ and $p=1.000$). A significant discrepancy was noted in ileostomy creation rates (RA 1.9% vs. OA 13%), despite comparable comorbidities and nutritional status between cohorts. Wound complications were comparable between cohorts (0.9% and 2.8%; $p=0.6138$).

Discussion

Robotic-assisted ileocolic resection for CD is in its early stage of adoption, as reflected by the paucity of data in this large database analysis and the lack of published reports on this subject. Our goal was to evaluate the early experience of elective robotic-assisted ileocolic resection for CD and compare these outcomes with the OA. Intestinal resection in patients with CD has been traditionally performed using an OA; however, minimally invasive techniques using laparoscopic and robotic-assisted approaches are gaining popularity. To the best of our knowledge, our study is the first evaluation of robotic-assisted approach for CD in the United States. The results demonstrate that, despite longer operative times, the RA approach was associated with a significantly shorter length of hospital stay, lower ileostomy creation rates, and a lower rate of 30-day postoperative complications compared to open ileocolic resection. In addition, the RA was associated with more home discharges compared to the OA.

The adoption of MIS ileocolic resection for CD has been relatively poor among surgeons, as it has been considered a technically challenging operation given the often severe inflammatory process frequently complicated by abscess, fistula, and a thick and foreshortened mesentery [8, 14]. In the setting of acute or chronic inflammation,

Table 2 Payor, hospital, and provider characteristics and year of surgery prior to and after propensity-score matching (PSM)

Characteristic	Prior to PSM			After PSM		
	Robotic-assisted ($N=109$)	Open ($N=1910$)	p value	Robotic-assisted ($N=108$)	Open ($N=108$)	p value
Payor, *n* (%)			0.0214			0.1087
Commercial	59 (54.1)	1166 (61.0)		58 (53.7)	67 (62.0)	
Medicaid	10 (9.2)	177 (9.3)		10 (19.3)	14 (13.0)	
Medicare	24 (22.0)	437 (22.9)		24 (22.2)	21 (19.4)	
Other	16 (14.7)	130 (6.8)		16 (14.8)	6 (5.6)	
Hospital						
Census region, *n* (%)			0.1916			0.1865
Midwest	15 (13.8)	356 (18.6)		15 (13.9)	16 (14.8)	
Northeast	26 (23.9)	446 (23.4)		26 (24.1)	30 (27.8)	
South	61 (56.0)	904 (47.33)		60 (55.6)	47 (43.5)	
West	7 (6.4)	204 (10.7)		7 (6.5)	15 (13.9)	
Location, *n* (%)			0.1681			0.3313
Urban	106 (97.2)	1785 (93.4)		105 (97.2)	101 (93.5)	
Rural	3 (2.8)	125 (6.5)		3 (2.8)	7 (6.5)	
Teaching status, *n* (%)			0.1014			0.2763
Academic	50 (45.9)	1039 (54.4)		50 (46.3)	59 (54.6)	
Community	59 (54.1)	871 (45.6)		58 (53.7)	49 (45.4)	
Number of beds, *n* (%)			0.5832			0.4725
0–99	3 (2.8)	125 (6.5)		3 (2.8)	2 (1.9)	
100–199	7 (6.4)	148 (7.7)		7 (6.5)	12 (11.1)	
200–299	13 (11.9)	235 (12.3)		13 (12.0)	10 (9.3)	
300–399	23 (21.1)	315 (16.5)		23 (21.3)	15 (13.9)	
400–499	11 (10.1)	298 (15.6)		11 (10.2)	16 (14.8)	
≥ 500	52 (47.7)	868 (45.4)		51 (47.2)	53 (49.1)	
Physician specialty, *n* (%)			0.0046			0.1192
Colorectal surgery	45 (41.3)	538 (28.2)		45 (41.7)	33 (30.1)	
General surgery	64 (58.7)	1372 (71.8)		63 (58.3)	75 (69.4)	

Table 3 Clinical outcomes after propensity-score matching

Variable	Robotic-assisted (RS) $N=108$	Open (OS) $N=108$	p value RS vs OS
Mean operating room time, min (mean ± SD)	240.7 (79.7)	181.0 (84.5)	< 0.0001
Conversion to open, *n* (%)	10 (9.3)	0 (0)	
Length of hospital stay, days			< 0.0001
Mean ± SD	6.2 (3.4)	7.8 (4.4)	
Median	5	7	
Discharge status, *n* (%)			0.2396
Health facility	2 (1.9)	3 (2.8)	
Home	106 (98.1)	105 (97.2)	
Deceased	0 (0)	0 (0)	
Mortality, *n* (%)			
Index hospital	0 (0)	0 (0)	

SD standard deviation of the mean

Table 4 Complications after propensity-score matching

Complications	Robotic-assisted (RS) $N=108$	Open (OS) $N=108$	p value RS vs OS
Complications, *n* (%)			
Intraoperative	3 (2.8)	3 (2.8)	1.0000
Postoperative	24 (22.2)	34 (31.5)	0.1671
Admission to 30 days	26 (24.1)	41 (38.0)	0.0395
Bleeding, *n* (%)			
Intraoperative bleeding	3 (2.8)	3 (2.8)	1.0000
Postoperative bleeding[a]	12 (11.1)	8 (7.4)	0.4813
Gastrointestinal, *n* (%)[b]			
Ileus	12 (11.1)	8 (7.4)	0.1303
Intestinal obstruction	4 (3.7)	4 (3.7)	1.0000
Wound, *n* (%)[b]			
Wound complications	1 (0.9)	3 (2.8)	0.6138
Superficial SSI	7 (6.5)	14 (13.0)	0.1682
Organ space SSI	8 (7.4)	10 (9.3)	0.8055
Other, *n* (%)[b]			
Pneumonia	2 (1.9)	4 (3.7)	0.6788
Deep venous thrombosis	1 (0.9)	0 (0)	1.0000
Urinary tract infection	3 (2.8)	3 (2.8)	1.0000
Acute renal failure	2 (1.9)	5 (4.6)	0.4422

SD standard deviation of the mean, *SSI* surgical site infection

[a]Postoperative bleeding that occurred through discharge

[b]Gastrointestinal, wound, and other complications included complications occurring from admission to 30 days

operative dissection and ileocolic mobilization can be challenging using a minimally invasive approach. This frequently requires conversion to an open approach, however with the advantages of improved visualization and operative dexterity with the robotic-assisted approach, these technical challenges could be potentially reduced and conversion rates decreased. Conversion rates to an OA in CD have been reported to range from 20 to 40% [15]. In this study, although operative times were longer with the RA, the conversion rate from RA to OA in the matched analysis was 9.3%. Because body mass index (BMI) and reoperative surgery are not uniformly reported in the Premier database, it is difficult to determine which characteristics influenced conversion. This conversion rate for robotic-assisted approach is still lower than what was referenced in the literature [15–17].

Reoperative surgery is common in patients with CD, with most patients undergoing their first resection during the third decade of life [18], which is similar to the findings of this analysis. Given the high probability of reoperative surgery in CD patients, a minimally invasive approach may allow for less difficult reoperations with the hypothetical reasons being less intra-abdominal adhesions and smaller abdominal incisions. Another factor that significantly impacts reoperation in CD patients is the presence of a stoma. Ileostomy creation was significantly higher in the OA cohort despite comparable comorbidities and nutritional status. Although it is unclear what factors contributed to this difference, it can be hypothesized that selection bias heavily influenced the OA.

The decision to create an anastomosis is mainly influenced by the degree of bowel and mesenteric inflammation, bowel-tissue quality, and patient-specific characteristics such as malnutrition and immunosuppression. While the RA may confer an advantage in performing an intracorporeal anastomosis by providing improved operative dexterity and visualization as well as robotic-assisted stapling, our analysis was unable to extract data regarding the technique of ileocolic anastomosis.

There are many limitations in this study and these include its retrospective nature, the lack of uniform and consistent reporting of CD characteristics including medical management, ASA scores, BMI, and status of reoperative surgery. We were also unable to address long-term outcomes such as CD recurrence, patient-perceived quality of life, and body image.

Conclusion

This early experience with elective RA ileocolic resection for CD demonstrated comparable, and in some instances, improved outcomes in postoperative length of hospital stay and 30-day postoperative complications compared to the OA. Our future research will aim at comparing the RA to the laparoscopic approach to further profile the potential benefits of the RA in CD patients.

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Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent For this retrospective, national database study, formal consent is not required.

Conflict of interest Elizabeth R. Raskin has received speaker honoraria from Intuitive Surgical. Madhu L. Gorrepati and Shilpa Mehendale are employees of Intuitive Surgical. Wolfgang B. Gaertner declares that he has no conflict of interest.

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