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ORIGINAL ARTICLE

Assessing robotic-assisted surgery versus open approach in penetrating Crohn's disease: advantages and outcomes in ileocolic resection

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Abstract

Introduction Penetrating Crohn's disease (CD) often necessitates surgical intervention, with the open approach traditionally favored. Robotic-assisted surgery offers potential benefits but remains understudied in this complex patient population. Additionally, the lack of standardized surgical complexity scoring in CD hinders research and comparisons.

Methods We retrospectively analyzed adult patients with penetrating CD who underwent either robotic-assisted ileocolic resection (RICR) or open ileocolic resection (OICR) at our institution from January 2007 to December 2021. We assessed endpoints, including length of stay, complications, readmissions, reoperations, and other perioperative outcomes.

Results RICR demonstrated safety outcomes comparable to OICR. Importantly, RICR patients experienced significantly reduced estimated blood loss ($p < 0.0001$), shorter hospital stays (median 4.5 days versus 6.9 days; $p = 0.01$), lower surgical site infection rates (0% versus 15.4%; $p = 0.01$), and decreased 30-day readmission rates (0% versus 15.4%; $p = 0.01$). Linear regression analysis revealed the need for additional strictureplasties (coefficient: 84.8; $p = 0.008$), colonic resections (coefficient: 41.7; $p = 0.008$), and estimated blood loss (coefficient: 0.07; $p = 0.002$) independently correlated with longer operative times).

Conclusion Robotic-assisted surgery appears to be a safe and potentially beneficial alternative for the surgical management of penetrating CD, offering advantages in perioperative outcomes reducing length of stay, blood loss, surgical site infection rates, and readmission rates. Further validation with larger cohorts is warranted.

Keywords Crohn's disease · Fistula · Robotic · Penetrating · Surgical score · Ileocolic resection

Introduction

Penetrating Crohn's disease (CD) represents a severe phenotype characterized by the development of fistulas between different segments of the intestine or between the intestine and other organs or skin [1, 2, 3]. The standard treatment for penetrating CD typically follows a step-up approach, with medical therapy as the initial intervention [4]. Anti-TNF agents, such as infliximab, have been demonstrated to effectively treat fistulas [5]. However, when medical interventions are proven ineffective, surgery becomes the recommended course of action [6]. The standard surgical procedure usually involves initial drainage of any associated abscess to minimize complications, followed by resection of the affected intestinal segments [7, 8, 9, 10, 11].

The complexity of surgical procedures for penetrating CD has limited the widespread adoption of the laparoscopic approach. Unlike uncomplicated CD, where laparoscopy is widely accepted due to its benefits—such as shorter hospital stays, fewer postoperative complications, reduced costs, and similar recurrence rates compared with traditional open techniques [6, 12]—the use of laparoscopy in penetrating CD is restricted to carefully selected patients. This cautious approach is reflected in the limited

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number of publications on the subject [13, 14, 15, 16]. Consequently, laparoscopy for penetrating CD should be considered primarily in highly trained inflammatory bowel disease (IBD) centers.

Furthermore, the complexity of penetrating CD has been underrepresented in surgical descriptors, complicating the comparison of treatment outcomes for similar case complexities.

This study aimed to assess the feasibility of robotic-assisted surgery in cases of penetrating CD compared with the traditional open approach, with the goal of identifying any significant differences in postoperative outcomes.

Methods

This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement guidelines for reporting observational studies [17].

Upon receiving approval from the institutional review board for human research, we accessed a prospectively maintained database. This dataset contained information on adult patients (≥ 18 years old) afflicted by penetrating CD (defined by the Montreal classification as B3) [18] who underwent ileocolic resection (ICR), utilizing both an open (OICR) or robotic (RICR) approach, at Mayo Clinic, Rochester. The data retrieval period extended from January 2007 to December 2021. Urgent, emergent, and enterocutaneous fistula cases were excluded from the final dataset.

Variables collected included patient characteristics [age, sex, body mass index (BMI), smoking status, diabetes, and history of prior abdominal surgery], CD characteristics (age at diagnosis, Montreal classification criteria A, previous use of biologics, biologic use within 12 weeks pre-surgery, steroid use within 4 weeks from surgery, and type and use of immunomodulators within 4 weeks pre-surgery), preoperative and operative data [preoperative hemoglobin, albumin, and C-reactive protein (CRP), surgical approach to ileocolic resection, type of anastomosis, additional procedures linked to ileocolic resection, type of fistula, target organ of the fistula, potential ostomy construction and type, operative time, and estimated blood loss (EBL)], and postoperative data (length of stay, 30-day complications, 30-day readmission, and 30-day reoperation).

The study's endpoints were length of hospital stay, 30-day complications, 30-day readmission, and 30-day reoperation.

All robotic procedures were completed using the robotic Da Vinci® Surgical System (Intuitive Surgical, Sunnyvale, California, USA).

Patients were categorized into two subgroups on the basis of an open or robotic approach.

Statistical methods

The study's findings were presented by reporting categorical variables as frequencies with percentages (%), while continuous variables were conveyed as median ± interquartile range (IQR). After failing the testing for normality with the Shapiro–Wilk test, a Mann–Whitney test was employed to compare quantitative variables. The χ^2 test or Fischer's exact test was applied as deemed appropriate for categorical variables. Statistical significance was set at a p-value of <0.05. A linear regression was performed to inspect relationships between preoperative and operative variables and the length of the surgical procedure. All statistical analyses were conducted using Stata 18 SE (StataCorp LLC, Texas, USA).

Results

Table 1 outlines the characteristics of 137 patients included in the study, of whom 33 underwent RICR and 104 underwent OICR. RICR patients were notably younger (32.4 ± 12.6 years versus 41.4 ± 15.5 years; $p=0.003$) and experienced a shorter interval between Crohn's disease diagnosis and surgery (6.7 ± 7.0 years versus 13.0 ± 12.0 years; $p=0.004$). Furthermore, the RICR group had used fewer biologics prior to surgery (0.6 ± 0.5 versus 1.1 ± 1.01; $p=0.004$) and had a lower rate of prior abdominal procedures (15.2% versus 57.7%; $p<0.001$). Differences were also observed in the type of biologics used within 12 weeks of surgery ($p=0.03$), with a higher rate of immunomodulator use in the OICR group (35.6% versus 6.1%; $p=0.001$).

Table 2 provides a comprehensive list of operative variables. The RICR group had a significantly higher rate of fistulas to the colon compared with the OICR group (24.2% versus 3.9%; $p<0.001$). Additionally, the OICR group experienced shorter operative times (166 ± 64 versus 228 ± 80 min; $p<0.001$) but had greater estimated blood loss (270 ± 60 versus 61 ± 52 ml; $p<0.001$). The RICR group also had a higher rate of stapled anastomoses ($p<0.001$) and side-to-side configurations ($p=0.003$). Conversely, the RICR group required fewer additional colonic resections (9.1% versus 33.7%; $p=0.007$) and fewer additional sigmoid resections (9.1% versus 32.7%; $p=0.007$).

Table 3 outlines the discrepancies in postoperative results between the two surgical approaches. Noteworthy observations include a shorter hospital stay for RICR patients (4.5 ± 6.1 versus 6.9 ± 4.7; $p=0.01$), a reduced SSI rate (0% versus 15.4%; $p=0.01$), and a lower 30-day readmission rate (0% versus 15.4%; $p=0.01$).

We performed a linear regression analysis to identify factors influencing operative time (Table 4). Several

Table 1 Patients' characteristics and preoperative data

Variables	All patients ($N=137$)	RICR ($N=33$)	OICR ($N=104$)	p-value
Male (%)	75 (54.7)	17 (51.5)	59 (55.8)	0.7[1]
Age at time of surgery, mean ± SD	39.3 ± 15.3	32.4 ± 12.6	41.4 ± 15.5	0.003[3]
Body mass index (kg/m^2), mean ± SD	23.8 ± 5.7	23.2 ± 5.4	24.0 ± 5.8	0.45[3]
Δ between age at diagnosis of CD and surgery, mean ± SD	11.5 ± 11.3	6.7 ± 7.0	13.0 ± 12.0	0.004[3]
Smoking (%)	22 (16.1)	3 (9.1)	19 (18.3)	0.3[2]
Diabetes (%)	4 (2.9)	0 (0)	4 (3.9)	0.6[2]
Prior abdominal surgery (%)	65 (47.5)	5 (15.2)	61 (57.7)	< 0.001[1]
Prior intestinal resections (%)	37 (27.0)	5 (15.2)	32 (30.8)	0.08[1]
Montreal classification criteria A (%)				0.2[2]
A1	23 (16.8)	9 (27.3)	14 (13.5)	
A2	92 (67.2)	20 (60.6)	72 (69.2)	
A3	22 (16.1)	4 (12.1)	18 (17.3)	
Active perianal disease at surgery (%)	12 (8.8)	5 (15.2)	7 (6.7)	0.14[1]
Any previous treatment with biologics (%)	82 (59.9)	19 (57.6)	63 (60.6)	0.8[2]
Number of previous biologics used (%)	1.0 ± 0.9	0.6 ± 0.5	1.1 ± 1.01	0.004[3]
Biologic type within 12 weeks from surgery (%)				0.03[2]
None	53 (38.7)	12 (36.4)	41 (39.4)	
Adalimumab	34 (24.8)	5 (15.2)	29 (27.9)	
Infliximab	29 (21.2)	7 (21.1)	22 (21.2)	
Certolizumab	4 (2.9)	1 (3.0)	3 (2.9)	
Vedolizumab	7 (5.1)	1 (3.0)	6 (5.8)	
Ustekinumab	10 (7.3)	7 (21.2)	3 (2.9)	
Systemic steroids within 3 months from surgery (%)	33 (24.1%)	10 (30.3)	23 (22.1)	0.34[1]
Immunomodulator use within 4 weeks from surgery (%)	39 (28.5)	2 (6.1)	37 (35.6)	0.001[2]
Preoperative hemoglobin (g/dl) within 2 weeks from surgery	12.4 ± 1.7	12.5 ± 1.8	12.4 ± 1.7	0.7[3]
Preoperative albumin (g/dl) within 4 weeks from surgery	3.9 ± 0.5	4.0 ± 0.5	3.8 ± 0.5	0.09[3]
Preoperative C-reactive protein (mg/L) within 2 weeks from surgery	32.4 ± 44.7	19.7 ± 27.7	37.3 ± 49.2	0.2[3]

[1]Chi-squared test

[2]Fisher's exact test

[3]Student's *t* test

factors associated with increased surgical complexity significantly predict longer operative times. These included the need for additional strictureplasty (coefficient: 84.8093; $p=0.008$), additional colonic resection (coefficient: 41.7758; $p=0.008$), and estimated blood loss (coefficient: 0.0731; $p=0.002$). Notably, the choice of RICR was also independently associated with a significant increase in operative time compared with the open approach (coefficient: 98.2334; $p<0.0001$). While not statistically significant, a trend toward longer operative times was observed in patients with a fistula to the retroperitoneum (coefficient: 56.2666; $p=0.051$) and those with prior intestinal resections (coefficient: 40.7408; $p=0.107$).

Discussion

This study demonstrates the efficacy of robotic-assisted surgery in penetrating CD. Notably, patients who underwent RICR demonstrated favorable outcomes, including a reduced EBL, shorter hospital stays, and lower rates of both surgical site infections (SSIs) and readmissions. These findings emphasize the potential benefits of employing robotic-assisted techniques in the surgical management of penetrating CD. Even more than 2 decades after introducing the robotic platform, a widely held belief is that the only viable approach is conventional laparotomy in

Table 2 Operative variables

Variables	All patients ($N=137$)	RICR ($N=33$)	OICR ($N=104$)	p-value
Fistula to the bladder (%)	13 (9.5)	2 (6.1)	11 (10.6)	0.7[2]
Fistula to the sigmoid colon (%)	65 (47.5)	12 (36.4)	53 (51.0)	0.1[1]
Fistula to the small bowel (%)	70 (51.1)	19 (57.6)	51 (49.0)	0.4[1]
Fistula to the colon (%)	12 (8.8)	8 (24.2)	4 (3.9)	<0.001[2]
Fistula to the retroperitoneum (%)	5 (3.7)	3 (9.1)	2 (1.9)	0.09[2]
Fistula to the duodenum (%)	2 (1.5)	1 (3.0)	1 (1.0)	0.4[2]
Operative time, mean ± SD (minutes)	182 ± 73	228 ± 80	166 ± 64	<0.001[3]
Estimated blood loss (ml), mean ± SD	219 ± 250	61 ± 52	270 ± 60	<0.001[3]
Presence of intra-abdominal abscess (%)	46 (33.6)	8 (24.2)	38 (36.5)	0.2[1]
Presence of phlegmonous mass (%)	19 (13.9)	3 (9.1)	16 (15.4)	0.6[2]
Primary anastomosis constructed (%)	132 (96.4)	33 (100)	99 (95.2)	0.3[2]
Anastomosis type (%)				<0.001[2]
Hand-sewn	39 (29.6)	0 (0)	39 (39.4)	
Stapled	93 (70.5)	33 (100)	60 (60.6)	
Anastomosis configuration (%)				0.003[2]
Side-to-side	102 (73.9)	33 (100)	69 (65.7)	
End-to-end	30 (21.7)	0 (0)	31 (28.5)	
Type of ileostomy if constructed (%)				0.8[2]
End	4 (16.7)	0 (0)	4 (18.2)	
End-loop	1 (4.2)	0 (0)	1 (4.6)	
Loop	19 (79.2)	2 (100)	17 (77.3)	
Additional small bowel resection (%)	10 (7.3)	0 (0)	10 (9.6)	0.06[2]
Additional strictureplasty (%)	4 (2.9)	4 (3.9)	0 (0)	0.6[2]
Additional colonic resection (%)	38 (27.7)	3 (9.1)	35 (33.7)	0.007[2]
Additional sigmoid resection (%)	37 (27.0)	3 (9.1)	34 (32.7)	0.007[2]
Associated suture or lateral stapling of the sigmoid colon (%)	21 (15.3)	7 (21.2)	14 (13.5)	0.3[1]
Associated repair of the duodenum (%)	2 (1.5)	1 (3.0)	1 (1.0)	0.4[2]
Associated repair of the bladder (%)	6 (4.4)	2 (6.1)	4 (3.9)	0.6[2]
Associated repair of the small bowel (%)	7 (5.1)	2 (6.1)	5 (4.8)	0.7[2]

MSS Mayo surgical score

[1]Chi-squared test, [2]Fisher's exact test, [3]Student's *t* test

complicated colorectal procedures, particularly in complex CD surgery. Despite the rapid expansion in the use of robotic procedures in the last 2 decades [19, 20] and the recommendations of minimally invasive approaches in published consensus and guidelines by surgical scientific societies [4, 21], open surgery continues to predominate in complex CD cases. However, our study revealed that the robotic platform showed equivalence and, in some cases, superiority to laparotomy. This was evident even when addressing challenging scenarios, such as patients with intra-abdominal abscess or phlegmon and cases requiring multivisceral resections. To effectively challenge and overcome this enduring conservative belief, advancing research in this domain and enhancing the availability of robotic surgery is crucial. Moreover, a key component is to invest in training both present and future generations of surgeons, focusing on procedures associated with IBD [22, 23, 24].

Another reason to underscore the importance of offering penetrating CD patients the option to undergo robotic procedures is evident in our series. In the RICR group, patients displayed a lower EBL, a decreased rate of readmissions, and a reduced occurrence of SSI compared with OICR. Consistent with existing literature, SSI proves to be a relatively common postoperative complication in CD patients, particularly those with fistulizing disease, with reported incidences ranging from 3% to 38% [25, 26, 27, 28, 29, 30]. Following Zhang and colleagues' findings, open abdominal surgery was associated with a higher incidence of SSI compared with minimally invasive approaches [31]. Therefore, in a population particularly susceptible to a specific complication, such as penetrating

Table 3 Differences in postoperative outcomes between RICR and OICR cohorts

Variables	All patients ($N=137$)	RICR ($N=33$)	OICR ($N=104$)	p-Value
Length of stay (days), median ± IQR	6 (3)	3 (2)	6 (3)	<0.0001[3]
30-day morbidity (%)	60 (43.8)	11 (33.3)	49 (47.1)	0.2[1]
Ileus (%)	22 (16.1)	5 (15.2)	17 (16.4)	0.8[1]
Surgical site infection (%)	16 (11.2)	0 (0)	16 (15.4)	0.01[2]
Intra-abdominal sepsis (%)	11 (8.0)	1 (3.0)	10 (9.5)	0.5[2]
Urinary tract infection (%)	12 (8.7)	4 (12.1)	8 (7.6)	0.5[2]
Pneumonia (%)	3 (2.2)	0 (0)	3 (2.9)	1.0[2]
Ileocecal leak (%)	10 (7.3)	1 (3.0)	9 (8.6)	0.5[2]
Postoperative blood transfusion (%)	16 (11.6)	3 (9.1)	13 (12.4)	0.8[2]
Small bowel obstruction requiring reoperation (%)	1 (0.7)	0 (0)	1 (0.9)	1.0[2]
Dehydration related to new stoma formation (%)	4 (2.9)	0 (0)	4 (3.9)	0.6[2]
Deep venous thrombosis (%)	2 (1.5)	0 (0)	2 (1.9)	1.0[2]
30-day readmission (%)	16 (11.6)	0 (0)	16 (15.4)	0.01[2]
30-day reoperation (%)	10 (7.3)	1 (3.0)	9 (8.6)	0.5[2]

[1]Chi–squared test, [2]Fisher's exact test, [3]Mann–Whitney test

Table 4 Linear regression for operative time (min)

Independent variable	Coefficient	p-value	95% confidence interval	
Body mass index (kg/m^2)	1.978247	0.389	0.4148617	3.541632
Number of previous biologics used	1.677244	0.924	−13.84732	17.20181
Biologic type within 12 weeks from surgery	−4.861306	0.356	−14.89869	5.176078
Systemic steroids within 3 months from surgery	2.744491	0.957	−23.31758	28.80656
Immunomodulator use within 4 weeks from surgery	6.807099	0.781	−18.94061	32.55481
Fistula to the bladder	−6.675503	0.606	−50.3187	36.96769
Fistula to the sigmoid colon	7.819528	0.684	−40.75161	56.39067
Fistula to the small bowel	30.28245	0.216	−1.163596	61.72849
Fistula to the colon	−1.853364	0.880	−47.58838	43.88165
Fistula to the retroperitoneum	56.26655	0.051	−0.9678375	113.5009
Fistula to the duodenum	3.318224	0.876	−90.51903	97.15548
Active perianal disease at surgery	−18.39735	0.530	−60.62059	23.82589
Prior intestinal resections	40.74083	0.107	13.47934	68.00233
Additional small bowel resection	9.161545	0.777	−42.06165	60.38474
Additional strictureplasty	84.8093	0.008	18.60464	151.014
Additional colonic resection	41.77576	0.008	−16.81146	100.363
Additional sigmoid resection	11.69714	0.770	−50.20306	73.59735
Associated suture or lateral stapling of the sigmoid colon	13.16666	0.932	−33.41658	59.7499
Associated repair of the duodenum	0	–	–	–
Associated repair of the bladder	15.07189	0.725	−46.86021	77.00399
Associated repair of the small bowel	−2.26155	0.872	−57.29576	52.77266
Robotic approach	98.23338	0.000	63.20406	133.2627
Primary anastomosis	15.01418	0.451	−32.66514	62.6935
Diverting ileostomy construction	29.66831	0.264	−4.525303	63.86193
Estimated blood loss (ml)	0.0731498	0.002	0.0276766	0.118623

CD patients, surgeons should strive to mitigate risks through any means.

Despite numerous advances in medical therapy, fistulizing CD remains a formidable challenge, associated with an elevated risk of morbidity and mortality, necessitating a multidisciplinary approach [32]. While the advent and development of various anti-TNF alpha agents have enhanced the care for patients affected by perianal fistulizing disease, there are still limited data on their effectiveness in managing phlegmons and abdominal fistulas [33, 34, 35]. This limitation is particularly notable given the diverse range of fistulas affecting patients. As a result, surgical resections remain crucial in treating penetrating CD, emphasizing the importance of making the best available treatment accessible to all patients.

This study is subject to several limitations. First, its retrospective design inherently constrains the scope of analysis and generalizability of findings. Additionally, the single-center nature of the study and the inherent selection bias toward younger and less complex patients in the robotic-assisted surgery group may limit the broader applicability of the findings. Second, the relatively small sample size of the RICR cohort, while significant in the context of existing literature on penetrating CD, may further limit broader applicability. Third, the extended data collection period necessary to amass sufficient cases could have introduced subtle variations in clinical practice, potentially impacting the results.

Fourth, the observed difference in prior abdominal surgery rates between the RICR and OICR groups introduces a potential confounding factor. Previous abdominal procedures can alter anatomical landmarks, potentially increasing surgical complexity regardless of the chosen approach.

Lastly, the diverse array of fistula types in Crohn's disease complicates direct patient comparisons. Future research, ideally a matched case–control study conducted across multiple centers, is warranted to further investigate the specific impact of robotic interventions on the management of penetrating CD and its various fistula subtypes.

Conclusion

RICR demonstrates broadly equivalent and safe outcomes in complex Crohn's surgery. Moreover, in penetrating CD patients, RICR offers significant advantages over OICR, including a minimally invasive approach that results in lower EBL, reduced SSI rates, shorter hospital stays, and lower readmission rates. Further studies with larger sample sizes are essential to validate these findings and determine the utility of the robotic approach in penetrating CD.

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Data availability No datasets were generated or analyzed during the current study.

Declarations

Conflicts of interest The authors declare no competing interests.

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

Informed consent Informed consent was obatined from all participants.

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