

Crohn's disease: is minimally invasive surgery the gold standard?

A narrative review

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Background and Objective: Minimally invasive surgery (MIS) is associated with reduced postoperative pain, shorter hospital stay, faster return to normal activity and diet, and improved cosmesis when compared to conventional open surgery. After the first laparoscopic ileocecal resections described in 1993, colorectal surgeons around the world started using multiport laparoscopic, single-port laparoscopic, and even robotic approaches for the surgical treatment of Crohn's disease (CD), from simple uncomplicated cases to more challenging forms of penetrating and recurrent disease, in order to achieve the mildest surgical stress and the best postoperative functional recovery. This narrative review aims to provide a comprehensive description of the forms of MIS currently used for the surgical treatment of CD.

Methods: We searched original papers and reviews, published by November 2022, about the applications of MIS in the operative management of CD using PubMed. Relevant studies were identified using different combinations of the following search terms: "Crohn's disease", "fistulizing Crohn's disease", "penetrating Crohn's disease", "recurrent Crohn's disease", "Crohn's colitis", "ileocecal resection", "laparoscopy", "laparoscopic surgery", "robotic surgery", "minimally invasive surgery", and "ERAS".

Key Content and Findings: We describe a variety of minimally invasive surgical approaches for the treatment of CD, from laparoscopic ileocecal resection for uncomplicated and complicated diseases, to laparoscopic colectomies and robotic-assisted procedures, focusing on the advantages of each technique in terms of short- and long-term outcomes.

Conclusions: It is unquestionable that MIS has demonstrated improved peri-operative results in the surgical management of CD, thus representing the current "gold standard" approach even in this patients' category, when appropriate expertise is available.

Keywords: Crohn's disease (CD); minimally invasive surgery (MIS); laparoscopic surgery; robotic surgery

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Introduction

Background

Minimally invasive surgery (MIS) encompasses the group of surgical techniques, introduced in the last decades of the 20th century, that is characterized by limited size of incisions, shorter recovery time and better post-operative outcomes.

Compared to the conventional open surgery, the minimally invasive surgical approach is associated with reduced postoperative pain, shorter hospital stay, faster return to normal activity and diet, improved cosmesis, lower incidence of incisional hernias, and reduced rate of post-surgical adhesions and related bowel obstructions (1,2).

It has been applied to multiple fields of abdominal surgery and has been further adopted, since its first application in elective cholecystectomy, even for complex benign and malignant abdominal diseases, like colonic diverticulitis and colon and rectal cancers.

Crohn's disease (CD) is an idiopathic chronic inflammatory bowel disease characterized by transmural involvement of virtually any portion of the gastrointestinal tract, from the oral cavity to the anal canal, although it preferentially affects the terminal ileum and the proximal colon. The incidence reaches 5 to 10 cases per 100,000 persons per year, with young adults (15–35 years) being the most affected (3). Although there have been improvements in the medical management of CD with the introduction of powerful and modern biologic drugs with immunomodulatory and anti-inflammatory action, a large proportion of CD patients (70–90%) (4) will require surgery during their lifetime for several reasons, mainly failure of medical therapy and a stenosing and/or fistulizing pattern of the disease, with the onset of obstructive symptoms and/or septic complications; moreover, up to 50% of patients who have undergone surgery require a second intervention within 10 years, and multiple procedures are necessary in up to 30% of patients, with a considerable risk of developing short bowel syndrome and intestinal failure because of multiple bowel resections (5).

Rationale and knowledge gap

Although the evidence of improved postoperative outcomes and cosmesis, the possibility of an early return to normal activities, and the lower incidence of intra-abdominal adhesions make MIS particularly appealing to the young population of CD patients, the application of this surgical

approach to CD had required more time than for other diseases, even those of a more malignant nature, with the first laparoscopic interventions described by Milsom *et al.* only in 1993 (6).

The main reasons underlying this delay were the perceived and/or actual technical difficulty encountered in CD, mainly due to the presence of inflammatory masses, abscesses, enteric fistulas, dilated intestinal loops, chronically inflamed and friable tissues, thickened mesentery, and, in the case of a recurrent disease, a subverted anatomy with multiple intra-abdominal adhesions (7).

Moreover, some authors have raised concerns about missing occult diseased intestinal segments or proximal bowel strictures due to limited tactile ability (8).

Hence, laparoscopic ileocolic resection for CD has been considered a difficult starting point for general surgeons wishing to perform minimally invasive colorectal surgical procedures.

A retrospective review by Evans, published in 2002, of all laparoscopic ileocolic resections for CD performed by a single surgeon demonstrated that the duration of the surgical procedure and the rate of conversion to open surgery follow a bimodal pattern: an initial peak due to the lack of expertise at the beginning of the learning curve and a second peak from facing increasingly complex cases, thus confirming the importance of adequate experience before attempting laparoscopic surgery for CD (9).

However, although technically demanding, minimally invasive procedures for CD have been proven to be feasible and safe in a variety of different scenarios, from the simple stenosing disease to more complex fistulizing and even recurrent forms, demonstrating the same advantages that minimally invasive surgery brings to other fields of abdominal surgery (10). In fact, laparoscopy is now considered the “gold standard” approach for surgical treatment of CD by many guidelines, even in complex and recurrent cases, if appropriate expertise is available (11).

Objective

The aim of this narrative review is to provide a timely analysis of the most updated and relevant evidence of the role of minimally invasive surgical procedures, focusing entirely on CD and evaluating almost all possible scenarios. We explore the success of laparoscopy in the treatment of simple, complex and recurrent ileocecal disease, describing and comparing a variety of techniques, from multiport to single-port and from video-assisted to fully laparoscopic

approaches. We also deal with the more rare and severe colonic involvement and the favorable outcomes of laparoscopic colectomies. Further, this review reports the promising but yet limited data on robotic surgery, questioning whether this new frontier has any chance of becoming the future for the surgical management of CD. Finally, we outline the Enhanced Recovery After Surgery protocol as part of the “minimally invasive strategy” to improve postoperative outcomes.

This review differs from previous ones (1,10,12) since it provides the reader with an accurate and comprehensive analysis of all the possible applications of minimally invasive surgery for the treatment of CD, describing the logical and chronological evolution of each technique and emphasizing the advantages with respect to traditional surgery. We present this article in accordance with the Narrative Review reporting checklist (available at <https://ales.amegroups.com/article/view/10.21037/ales-22-75/rc>).

Methods

We searched original papers and reviews, published up to November 2022, about the applications of minimally invasive surgery in the operative management of CD using PubMed. Relevant studies were identified using different combinations of the following search terms: “Crohn’s disease”, “fistulizing Crohn’s disease”, “penetrating Crohn’s disease”, “recurrent Crohn’s disease”, “Crohn’s colitis”, “ileocecal resection”, “laparoscopy”, “laparoscopic surgery”, “robotic surgery”, “minimally invasive surgery”, and “ERAS”.

Additional papers were identified by reviewing reference lists of relevant publications. Publications with relatively low credibility and in languages other than English were excluded. Data were extracted based on their relevance to the topic instead of by implementing a systematic approach to paper selection. More details of the method are shown in Table 1.

Discussion

Ileocecal resection for uncomplicated CD

The first series of laparoscopic resections on CD were described by Milsom *et al.* in 1993 on 9 patients with primary stenosing uncomplicated ileocecal disease.

Once the feasibility and safety of laparoscopy in this patient subset had been assessed, several authors tried

to compare laparoscopically assisted and conventional open ileocolic resection, aspiring for the same favorable postoperative outcomes already described in oncological procedures.

At the beginning of the twenty-first century, Alabaz *et al.* published the results of their retrospective analysis of 74 patients who received ileocolic resection for primary stenosing CD. The authors demonstrated a shorter hospital stay, better cosmetic results, faster return to normal activities, improved social and sexual lives, and lower incidence of symptomatic bowel obstruction at a mean follow-up of 30 months in the laparoscopic group compared with the conventional open group, at the cost of longer operating times (13).

Other retrospective studies confirmed the same results and further demonstrated faster resumption of regular dieting, reduced necessity for narcotics, reduced blood loss, and lower direct costs in patients who underwent laparoscopic ileocecal resection compared to the conventional open group, with a comparable complication rate, morbidity, and 5-year recurrence rate (14–21).

The conversion rate ranged between 4.8% and 29.2%, with bleeding, adhesion, masses, fistulas, inability to deliver specimen, and suspected carcinoma being the main reasons for conversion (12). These data are in line with conversion rates from colorectal resections performed for oncological disease, with a mean conversion rate of 14.3%, where right colectomy has the lowest conversion rate (12.9%) and proctectomy has the highest conversion rate (31.2%) (22).

As regards the duration of surgery, data from tertiary referral centers with high surgical volumes reported no difference in operative time between laparoscopic and open procedures (136.0 ± 44.4 vs. 119.5 ± 35.6 min, respectively), compared to centers with fewer than eight cases per year, in which the duration of surgery was significantly longer in the laparoscopic group, thus implying a relevant learning curve associated with the laparoscopic approach for the surgical treatment of this complex disease (12,20). In fact, when considering high-volume centers, data on laparoscopic operative time are comparable to those reported for laparoscopic right hemicolectomy for oncological disease (133.0 ± 4.7 min) (23).

Although a totally laparoscopic resection with intracorporeal vascular division and anastomosis construction has been found to be safe and feasible in selected patients with CD of the terminal ileum (24), the mainly adopted surgical technique consists in a laparoscopic-assisted approach rather than a fully laparoscopic procedure,

Table 1 The search strategy summary

Items	Specification
Date of search	2022/11/30
Databases and other sources searched	PubMed
Search terms used	“Crohn’s disease” [MeSH] AND “laparoscopic surgery” [MeSH] “Crohn’s disease” [MeSH] AND “minimally invasive surgery” [MeSH] “fistulizing Crohn’s disease” [MeSH] AND “laparoscopic surgery” [MeSH] “penetrating Crohn’s disease” [MeSH] AND “laparoscopic surgery” [MeSH] “recurrent Crohn’s disease” [MeSH] AND “laparoscopic surgery” [MeSH] “Crohn’s colitis” [MeSH] AND “laparoscopic surgery” [MeSH] “ileocecal resection” [MeSH] AND “laparoscopic surgery” [MeSH] “fistulizing Crohn’s disease” [MeSH] AND “minimally invasive surgery” [MeSH] “penetrating Crohn’s disease” [MeSH] AND “minimally invasive surgery” [MeSH] “recurrent Crohn’s disease” [MeSH] AND “minimally invasive surgery” [MeSH] “Crohn’s colitis” [MeSH] AND “minimally invasive surgery” [MeSH] “ileocecal resection” [MeSH] AND “minimally invasive surgery” [MeSH] “Crohn’s disease” [MeSH] AND “robotic surgery” [MeSH] “Crohn’s disease” [MeSH] AND “ERAS” [MeSH]
Timeframe	1990–2022
Inclusion and exclusion criteria	Focus was placed on original papers and reviews in English about minimally invasive surgical techniques for the treatment of CD; publications with relative low credibility and non-English publications were excluded
Selection process	It was conducted independently by Luglio G, Cricri M and Tropeano FP; all authors discussed the literature selection and obtained the consensus
Any additional considerations, if applicable	Some papers were identified by reviewing reference lists of relevant publications
CD, Crohn’s disease.	

with only right colon mobilization realized laparoscopically and followed by exteriorization of the bowel through a short skin incision to allow for extracorporeal vascular division and anastomosis construction, mainly for safety reasons on account of manipulating a friable, thick and hypervascular mesentery (14).

Apart from dealing safely with inflammatory masses and fragile mesenteries, a mini-laparotomy makes it possible to manually explore the entire bowel and detect skip lesions that would be difficult to detect and assess with a fully laparoscopic view. More importantly, a mini-laparotomy permits the surgeon to perform strictureplasties and a variety of different hand-sewn anastomoses, even the most technically demanding. In this regard, the novel hand-sewn Kono-S anastomosis, which is known to reduce endoscopic

and surgical recurrence rates (25–27), can be perfectly performed after laparoscopic bowel mobilization and exteriorization through a midline mini-laparotomy, thus combining the beneficial short-term outcomes associated with a minimally invasive procedure with long-term optimal disease control.

Some authors have also described a single-incision laparoscopic surgery (SILS) with the hope to further minimize minimally invasive surgery. This approach is based on the creation of a single incision through which several laparoscopic instruments can be used, providing improved cosmetic results over the “traditional” multiport laparoscopy. Although safe and feasible, single-incision laparoscopic ileocecal resection does not result in improved peri-operative outcomes with respect to multiport

laparoscopy, and the higher technical demand makes the adoption of this procedure limited by the surgeon's experience and personal preference (28-30).

Going back to minimally invasive laparoscopic surgery, the encouraging results of early retrospective studies were confirmed by prospective non-randomized studies (31-33) and randomized controlled trials (RCTs) (34-37) on the same topic, as well as by meta-analyses and systematic reviews (12,38-40), with additional hints on possible favorable fertility outcomes in female patients who undergo laparoscopic surgery and more solid evidence even for long-term outcomes. Among these, postoperative recurrence rate has been studied, with several meta-analyses and RCT comparing the two surgical approaches in terms, reporting a recurrence rate of laparoscopy as low as 0% and as high as 30%.

In 2005, Rosman *et al.* (39) published a meta-analysis on 16 studies that reported a lower recurrence rate in laparoscopically treated patients; a statistically significant difference was observed in only one study. The possible reason behind these data may reside in the fact that the lower complication rate associated with laparoscopic surgery translates into a lower recurrence rate, since disease recurrence is closely associated with postoperative septic complications (41). More recent meta-analyses (1) and RCT (35,36), however, failed to demonstrate a statistically significant advantage of laparoscopic surgery in terms of surgical recurrence over open surgery, making this topic still open to debate.

In conclusion, for its superior short-term and long-term outcomes, laparoscopic surgery has become the approach of choice for CD patients with primary stenosing and/or uncomplicated disease, depending on the surgeon's expertise (11).

Analyzed studies are summarized in *Table 2*, with the main limitations of each study briefly described.

Ileocecal resection for complex fistulizing CD

Fistulizing CD is a pattern of disease characterized by the formation of abscesses, phlegmons and fistulas between diseased intestinal segments and the surrounding, often healthy, victim organs, which are mainly represented by other bowel loops, the sigmoid colon and the urinary bladder.

Historically considered a contraindication to minimally invasive surgery, complex fistulizing CD has been lately approached by skilled colorectal surgeons laparoscopically, with better outcomes compared to open surgery, but

with worse outcomes compared to uncomplicated CD, as expected.

Bellolio *et al.* reported data on 434 CD patients, 293 of whom had fistulizing CD. This group of patients with fistulizing CD was more likely to require preoperative total parenteral nutrition, to have a temporary ileostomy and longer duration of hospital stay, and to develop postoperative abscess or leak, and was less likely to undergo a laparoscopic surgical procedure (42).

Minimally invasive surgery for complex CD was assessed to be safe and technically feasible in 2002 by Watanabe *et al.*, who reported good results from twenty patients that underwent laparoscopic surgery for CD associated with fistulas, with acceptable conversion and complication rates (16% each) (43).

The presence of intra-abdominal abscesses or fistulas at the time of laparoscopy was determined as an independent risk factor for conversion to open surgery in a prospective study of 69 patients conducted by Alves and colleagues in 2005 (44). Okabayashi *et al.*, in 2007 (45), reported greater conversion rates and major complications in a B3 subgroup of CD patients. Other risk factors associated with higher odds of conversion to open surgery are recurrent medical episodes of CD, previous ileocolic open resection and longer operation time, which is related to less surgical experience, stressing the need for greater surgical skills to face such complex and severe cases (44,46).

Goyer *et al.*, in 2009, compared 54 laparoscopic ileocolic resections for penetrating CD with 70 laparoscopic ileocolic resections for non-penetrating stenosing CD. Although safe and feasible, laparoscopic surgery for complex CD was associated with increased mean operative time, increased conversion rate to open procedure, increased use of temporary stoma, and comparable postoperative morbidity with respect to the uncomplicated CD group, suggesting that laparoscopic ileocolic resection should not be limited to uncomplicated patients (47).

Further confirmation of the suitability of the laparoscopic procedure came from Melton's analysis of the surgical treatment of ileo-sigmoid fistulas, reporting lower stoma rate, fewer additional small bowel procedures and shorter hospital stay with respect to the open surgery group (48). Beyer-Berjot *et al.* reported good perioperative outcomes of 11 patients who underwent laparoscopic ileocolic resection for penetrating disease with different entero-visceral fistulas (49).

Since the presence of pus in the operative field has been associated with a higher risk of laparotomy and anastomotic dehiscence and with increased stoma rate

Table 2 Summary of analyzed studies about Ileocolic resection for uncomplicated CD

Study	Patient No.	Methods	Participants	Intervention	Outcomes	Conclusions	Limitations
Alabaz <i>et al.</i> , 2000 (13)	74 (48 O, 26 L)	Non-randomized	CD patients	ICR	ST, LT	O: shorter operating time L: shorter hospital stay, faster return to work activity, better cosmesis, improved social and sexual lives, fewer bowel obstruction	Retrospective
Bemelman <i>et al.</i> , 2000 (14)	78 (48 O, 30 L)	Non-randomized	CD patients	ICR	ST	O: shorter operating time L: shorter hospital stay Conversion rate: 6.6%	Two groups treated in different hospitals by different surgeons
Milsom <i>et al.</i> , 2001 (37)	60 (29 O, 31 L)	RCT	CD patients	ICR	ST	L: faster pulmonary recovery, fewer minor complications, shorter length of stay	The surgical stuff became more experienced and new technologies more available during the long study period
Young-Fadok <i>et al.</i> , 2001 (18)	66 (33 O, 33 L)	Non-randomized	CD patients	ICR	ST	L: shorter time to fluid and regular diet, shorter hospital stay, lower direct and indirect costs Conversion rate: 5.9%	Comparison with historical case-matched cohort with different surgeons and postoperative care
Duepre <i>et al.</i> , 2002 (16)	45 (24 O, 21 L)	Non-randomized	CD patients	ICR	ST	L: faster resumption of oral intake and intestinal function, shorter hospital stay, lower direct cost per case Conversion rate: 4.8%	Different surgeons performing the procedures
Benoist <i>et al.</i> , 2003 (15)	56 (32 O, 24 L)	Non-randomized	CD patients	ICR	ST	No difference in terms of operating time, resumption of bowel function and mortality rate Conversion rate: 17%	It includes some patients with penetrating disease Comparison with historical case-matched cohort
Shore <i>et al.</i> , 2003 (17)	40 (20 O, 20 L)	Non-randomized	CD patients	ICR	ST	O: shorter operating time L: lower blood loss, faster bowel function recovery, earlier resumption of regular diet, shorter hospital stay, lower costs Conversion rate: 5%	Retrospective analysis of a prospective database It includes some patients with penetrating disease
Bergamaschi <i>et al.</i> , 2003 (21)	92 (53 O, 39 L)	Non-randomized	CD patients	ICR	ST, LT	O: shorter operating time L: shorter hospital stay, fewer bowel obstruction Conversion rate: 0%	Underpowered for surgical complication rates
Huilgol <i>et al.</i> , 2004 (20)	40 (19 O, 21 L)	Non-randomized	CD patients	ICR	ST	O: shorter operating time L: faster resumption of liquid and solid diet, faster return of bowel function, shorter hospital stay	4 of 21 patients having L resections had synchronous colonic or rectal procedures not planned preoperatively

Table 2 (continued)

Table 2 (continued)

Study	Patient No.	Methods	Participants	Intervention	Outcomes	Conclusions	Limitations
Maartense <i>et al.</i> , 2006 (34)	60 (30 O, 30 L)	RCT	CD patients	ICR	ST	O: shorter operating time L: shorter hospital stay, lower 30-days morbidity rate, lower costs Conversion rate: 10%	Unclear postoperative care
Fichera <i>et al.</i> , 2007 (32)	146 (87 O, 59 L)	Non-randomized	CD patients	ICR	ST, LT	L: less blood loss, less analgesic requirement, shorter hospital stay, similar operating time	Non-randomized, mainly focusing on short term outcomes
Sica <i>et al.</i> , 2008 (31)	28 (13 O, 15 L)	Non-randomized	CD patients	ICR	ST	O: shorter operating time L: shorter hospital stay, faster resumption of regular diet, lower dosage of pain killers needed	Small sample size
Stocchi <i>et al.</i> , 2008 (35)	56 (29 O, 27 L)	RCT	CD patients	ICR	LT	L: during follow-up, lower need of further surgical operations	The O group included some patients with penetrating disease No data about quality of life
Eshuis <i>et al.</i> , 2010 (36)	55 (26 O, 29 L)	RCT	CD patients	ICR	LT	L: better body image and cosmesis, lower rate of incisional hernias and bowel obstructions. Comparable quality of life	Data on quality of life impaired by the low relapse rate
Makni <i>et al.</i> , 2013 (19)	129 (65 O, 64 L)	Non-randomized	CD patients	ICR	ST, LT	O: shorter operating time L: shorter hospital stay, faster bowel recovery, faster resumption of regular diet, lower recurrence rate at 26 months mean follow-up	Non-randomized retrospective analysis of a prospective database
Wan <i>et al.</i> , 2021 (33)	120 (20 O, 100 L)	Non-randomized	CD patients	ICR	ST	L: shorter hospital stay, faster bowel recovery, faster resumption of regular diet, less intraoperative blood loss; comparable operation time and complication rate	Non-randomized No long-term outcomes

RCT, randomized control trial; CD, Crohn's disease; ICR, ileocecal resection; ST, short-term outcomes; LT, long-term outcomes; O, open; L, laparoscopic.

(44,48,50), preoperative optimization is always advisable in patients with fistulizing CD with evidence of an intra-abdominal abscess, and mainly consists of malnutrition, anemia, and intra-abdominal infection management. The latter can be achieved either with antimicrobial therapy or percutaneous drainage, or both, especially for abscesses larger than 3 cm; when successful, percutaneous drainage prevents emergency surgery in up to 30% of patients, and can be considered a bridge to elective surgery, increasing the likelihood of performing a laparoscopic procedure and reducing the rate of stoma construction and postoperative complications (11,51,52).

In conclusion, fistulizing CD is surely a complex situation to deal with, and a laparoscopic approach may be difficult in such a situation, with conversion rates as low as 9% and as high as 40%, mainly depending on the presence of intra-abdominal abscesses, recurrent medical episodes and poor surgical experience; nevertheless, when feasible and with adequate surgical skills, MIS in complex penetrating CD has shown better postoperative outcomes, lower stoma rate and fewer additional small bowel procedures than the conventional approach. Nutritional, pharmacological and radiological preoperative patient optimization is then pivotal, and must be considered as the initial part

Table 3 Summary of analyzed studies about Ileocolic resection for penetrating CD

Study	Patient No.	Methods	Participants	Intervention	Outcomes	Conclusions	Limitations
Watanabe <i>et al.</i> , 2001 (43)	20	Series	PD patients	Several laparoscopic procedures	ST	Median time to oral intake: 1 day Median length of stay: 8 days Complication rate: 16% Conversion rate: 16%	Case series with small sample size; different surgical procedures
Alves <i>et al.</i> , 2005 (44)	69 (21 converted, 48 fully laparoscopic)	PS	CD patients with different disease features	Laparoscopic ICR	ST	PD: higher conversion rate Converted patients had longer hospital stay	
Okabayashi <i>et al.</i> , 2006 (45)	91	Series	CD patients with different disease features	Several laparoscopic procedures	ST	PD: higher conversion and complication rates	Case series; different surgical procedures
Goyer <i>et al.</i> , 2009 (47)	124 (54 PD, 70 NPD)	Non-randomized	CD patients	Laparoscopic ICR	ST	PD: longer operating time, increased conversion rate. Increased use of temporary stoma, similar overall postoperative morbidity	Higher stoma rate affected by the low threshold for two-stage procedures by the surgical team in difficult cases
Melton <i>et al.</i> , 2009 (48)	104 (75 O, 29 L)	Non-randomized	CD patients with ileosigmoid fistulas	ICR + sigmoid colon primary repair, segmental resection or subtotal colectomy	ST	L: lower stoma rate, fewer additional small bowel procedures, longer hospital stay	Non-randomized; different surgical procedures
Bellolio <i>et al.</i> , 2013 (42)	434 (293 PD, 141 NPD)	RS	CD patients	ICR	ST	PD: higher need for preoperative total parenteral nutrition, need for another resection, higher ileostomy rate, longer hospital stay, lower rate of laparoscopic procedure	Retrospective
Beyer-Beriot <i>et al.</i> , 2013 (49)	33 (11 PD, 22 NPD)	Retrospective case-match	CD patients	Laparoscopic ICR	ST	No significant differences between the two groups in terms of peri-operative outcomes	Retrospective. Small sample size

RS, retrospective study; PS, prospective study; CD, Crohn's disease; ICR, ileocecal resection; ST, short-term outcomes; PD, penetrating disease; NPD, non-penetrating disease; O, open; L, laparoscopic.

of a minimally invasive approach, which culminates into laparoscopic elective surgery when feasible.

Analyzed studies are summarized in *Table 3*, with the main limitations of each study briefly described.

Ileocolic resection for recurrent CD

Due to the relapsing nature of CD, up to 50% of patients who undergo surgery require a second intervention within 10 years, with multiple procedures necessary in up to 30%

of patients.

While the advantages of minimally invasive surgery are evident and straightforward in primary ileocolic resection for uncomplicated CD, its application in recurrent CD is more challenging both technically and theoretically, especially after an open procedure with consequent altered cosmesis and abdominal anatomy for adhesions.

Wu *et al.*, in 1997, were the first to demonstrate the safety and feasibility of a laparoscopic approach for recurrent CD, originally considered a contraindication to minimally

invasive surgery together with penetrating CD. In their study, 46 laparoscopic ileocecal resections, of which 10 were performed for the recurrent disease and the remaining for the penetrating and uncomplicated disease, were compared to 70 open procedures. Laparoscopic ileocolic resection was found to be safe and feasible even in the recurrent disease group, with shorter operating time and length of hospital stay and lower estimated blood loss than in the open group, and with conversion to open surgery occurring in 20% of cases, mainly due to extensive adhesions (53).

Preliminary retrospective studies comparing laparoscopic ileocecal resection in primary CD versus recurrent CD demonstrated increased conversion rate and longer operative times and length of hospital stay, with comparable overall postoperative morbidity (47,54).

Also, a prospective study by Chaudhary *et al.* confirmed longer operative times in the recurrent group, and a conversion rate of 8.5%; in addition, the authors demonstrated that recurrent patients with conversions had longer hospital stay and higher morbidity than cases completed laparoscopically (55).

However, a larger study of 130 patients in the Cleveland Clinic showed similar results between laparoscopic primary and recurrent groups, demonstrating how, with increasing laparoscopic experience, operative times shorten and the overall benefits of minimally invasive surgery become more evident even in recurrent CD patients (56).

The beneficial effects of minimally invasive surgery in redo ileocolic resection have been further proven by an interesting study by Holubar *et al.*, in which 30 patients who underwent a fully laparoscopic procedure were compared to 10 patients whose laparoscopic procedures were converted into open surgery for extensive adhesions. The converted group was associated with increased time to regular diet (4 versus 3 days) and longer length of hospital stay (7 versus 4 days), with no difference in terms of post-operative complications (57).

Even patients with previous multiple laparotomies could benefit from laparoscopic surgery, as demonstrated in a 2018 study by Celentano *et al.* The authors conducted a prospective analysis of 29 recurrent CD patients with 2, 3 or 4 previous laparotomies and 90 patients with no history of abdominal surgery, showing the safety and feasibility of laparoscopic redo ileocolic resection, at the expense of longer operating time (58).

In conclusion, despite the technical difficulties encountered for a disrupted anatomy and a hostile abdomen, recurrent CD should not be considered an

absolute contraindication to minimally invasive surgery, which can offer, even in this group of patients, favorable outcomes, especially when performed by an experienced surgeon.

Analyzed studies are summarized in *Table 4*, with the main limitations of each study briefly described.

Colectomy for Crohn's colitis

Colonic involvement in CD is less common than ileal or ileocolic localization, but it is still characterized by a high risk of postoperative complications and recurrence following extensive and often debilitating surgical procedures, including segmental colectomy, subtotal colectomy with ileorectal anastomosis and total proctocolectomy with end ileostomy.

Preliminary results on minimally invasive colectomies for several colorectal pathologies, including CD, demonstrated a reduction in postoperative nausea and vomit, length of ileus and hospitalization in patients who underwent laparoscopic procedures compared to those who underwent open surgeries, with significantly longer operative times (59).

Holubar *et al.* reported data from a single institution experience for 92 patients affected by Crohn's colitis who underwent straight laparoscopic or hand-assisted laparoscopic total, subtotal or segmental colectomy from 1997 to 2008. Conversion occurred in 16% of cases, mainly due to the presence of phlegmon, fistula or concurrent terminal or proximal small bowel involvement, and the overall postoperative length of hospital stay was 5 days. Postoperative complications occurred in 34% of patients, mainly of the minor entity (Grades 1 and 2) and more commonly in the total colectomy group (60).

Umanskiy and colleagues compared short-term postoperative outcomes of laparoscopic colectomy and open procedure in 125 patients with Crohn's colitis, demonstrating decreased blood loss, quicker bowel recovery, shorter length of stay and, more strikingly, decreased operative time in the laparoscopic, with a relatively low conversion rate (10.9%); however, it is worth noting that patients were selected for type of surgical procedure based on the surgeon's preference, with lower incidence of previous abdominal surgery in the laparoscopic group, leading to selection bias (61,62).

Favorable outcomes associated with laparoscopic surgery for colonic CD were confirmed by a large multicentric study promoted by the Italian Society of Colorectal Surgery. Indeed, on multivariate analysis, laparoscopic surgery was

Table 4 Summary of analyzed studies about Ileocolic resection for recurrent CD

Study	Patient No.	Methods	Participants	Intervention	Outcomes	Conclusions	Limitations
Wu <i>et al.</i> , 1997 (53)	70 O vs. 46 L	Non-randomized	CD patients with different disease features	ICR	ST	Laparoscopic ICR in RD group was associated with less operative blood loss, shorter operating time and hospital stay with respect to Open group	Non-randomized; heterogeneous patient population
Goyer <i>et al.</i> , 2009 (47)	124	Non-randomized	CD patients (54 PD + RD, 70 uncomplicated disease)	Laparoscopic ICR	ST	PD + RD: longer operating time, increased conversion rate, higher stoma rate Comparable postoperative morbidity Conversion rate: 37%	Higher stoma rate may be affected by the low threshold for two-stage procedures by the surgical team in difficult cases
Pinto <i>et al.</i> , 2011 (56)	130 (50 RD, 80 NRD)	RS	CD patients	Laparoscopic ICR	ST	Comparable operative time, conversion, stoma and early complication rates	Retrospective case-control series; heterogeneous patient population
Chaudhary <i>et al.</i> , 2011 (55)	59 (30 RD, 29 NRD)	Non-randomized	CD patients	Laparoscopic ICR	ST	RD: longer operating time Conversion rate: 8.5% Converted patients had longer hospital stay and higher morbidity	Small sample size
Holubar <i>et al.</i> , 2010 (57)	40 (30 completely laparoscopic, 10 lap-converted)	Non-randomized	RCD patients	ICR	ST	Laparoscopic-converted: higher need for adhesiolysis, longer time to soft diet, longer hospital stay	Retrospective; small sample size
Celentano <i>et al.</i> , 2018 (58)	119 (29 RD, 90 NRD)	Non-randomized	CD patients	Laparoscopic ICR	ST	RD: longer operating times No significant differences between the two groups in terms of morbidity and conversion rate	Small RD group; long study period, with cases being performed at different stages of learning curve

O, open; L, laparoscopic; RS, retrospective study; CD, Crohn's disease; ICR, ileocecal resection; ST, short-term outcomes; RCD, remission CD; RD, recurrent disease; NRD, non-recurrent disease; PD, penetrating disease.

associated with reduced postoperative morbidity and shorter length of hospitalization, with recurrent CD associated with conversion to an open approach (62).

In conclusion, while MIS for ileocecal resection in CD has been well established and extensively studied, there are limited studies on colonic CD, but these few demonstrate the safety, feasibility and favorable outcomes generally associated with the minimally invasive approach, with acceptable conversion rates and operative times.

Robotic surgery in CD

Robotic surgery is a new frontier of minimally invasive

surgery that aims to overcome the limitations of laparoscopic surgery. Here, the surgeon controls, from a console distant from the operative field, robotic arms and instruments characterized by improved manual dexterity with multiple degrees of freedom, magnified high-definition 3-dimensional visualization, and tremor abolition, with the possibility of simultaneous use of multiple energy devices (63).

Robotic surgery has been demonstrated to be feasible and safe in colon and rectal surgery for both benign and malignant diseases. In a malignant disease setting like colon cancer, robotic and laparoscopic right colectomies showed a comparable length of hospital stay, surgical complication rate, postoperative pain score, resection margin clearance,

number of lymph nodes harvested, and conversion to open surgery, but the robotic approach was burdened with longer operative times and higher hospital costs (64).

In recent years, robotic surgery has been increasingly applied to ileocecal resections in patients with CD and compared to conventional open or laparoscopic surgery.

In 2018, Raskin and colleagues provided an early experience with elective robotic ileocecal resection for CD, obtaining short-term outcomes from a retrospective analysis of 108 CD patients who underwent elective robotic-assisted ileocecal resection compared with another cohort of 108 patients treated with the conventional open surgical approach. Although robotic-assisted procedures were longer by a mean of 60 minutes, they were associated with a shorter length of hospital stay by a median of 2 days and a lower incidence of 30 days' complication rate, confirming the same benefits of robotic surgery over open surgery reported in cancer patients (65).

In 2020, Aydinli *et al.* retrospectively compared perioperative data between 33 patients who underwent robotic-assisted ileocecal resection and 14 patients treated with a laparoscopic procedure. The two groups demonstrated comparable intraoperative (conversion rate, estimated blood loss, intraoperative complications) and postoperative outcomes (length of hospital stay, overall complication rate, reoperation rate), with the exception of operative time and time to bowel function, which were respectively longer by 51 minutes and shorter by 1 day in the robotic group (66).

Data from the first large scale study to comprehensively evaluate the perioperative outcomes of laparoscopic, robotic and open surgery in CD patients who underwent ileocecal resection were published by Hota and colleagues in 2020. The open surgery group reported prolonged ileus and significantly higher anastomotic leak, reoperation and wound infection rates. When robotic and laparoscopic approaches were compared, the perioperative outcomes were similar, with the exception only of the operative time, which was longer in the former group (67).

In conclusion, despite the promising postoperative results of robotic surgery compared to open surgery, it is still questionable whether the higher costs and longer operative time compared to laparoscopic surgery justify its use, even for ileocecal resection in CD patients.

Enhanced recovery after surgery (ERAS) protocol in CD

When considering short-term postoperative outcomes, adequate pre-surgical preparation and post-surgical

recovery protocol are essential to further minimize the invasiveness of the surgical act.

In 1997, Kehlet proposed a multimodal intervention program aimed at improving the undesirable sequelae of major surgery, such as pain, prolonged ileus, and cardiopulmonary and infective complications, and ensuring faster recovery. It was this proposal that gave rise to the ERAS protocol (68).

Multidisciplinary patient information, no fasting, no preoperative midazolam administration, use of ultrashort acting opioids, fluid restriction, nasogastric tube removal on awakening, early mobilization, early fluid and solid intake, and urinary catheter removal on the first postoperative day are the pillars of the enhanced recovery pathway (69).

ERAS was originally coupled with open surgery in order to temper the massive surgical stress following major conventional procedures. However, when laparoscopic surgery started to be globally adopted for a variety of abdominal interventions, the ERAS protocol was not abandoned but was rather combined with laparoscopy to potentiate its minimal invasiveness. The addition of ERAS to a variety of laparoscopic procedures, including colectomies, showed improved post-operative outcomes, with a 2-day reduction in length of stay and a faster return to bowel function (70).

A multicentric prospective study by Esteban *et al.* evaluated the impact of the ERAS protocol in colorectal cancer patients who underwent elective open or laparoscopic procedures. The authors demonstrated that the combination of laparoscopic surgery and the enhanced recovery protocol resulted in the shortest hospital stay (5 days) and least morbidity (71).

The first experience of the adoption of the ERAS protocol after ileocolic resection for CD was in 2012 through a case-matched study. By comparing twenty patients who underwent laparoscopic ileocecal resection for CD using the enhanced recovery protocol with a matched historical group of 70 CD patients who underwent the laparoscopic procedure with conventional postoperative care, Spinelli *et al.* demonstrated that the ERAS group was associated with reduced time to first flatus and stool and shorter mean length of stay (69).

Other studies (72,73), meta-analyses and systematic reviews (74,75) have confirmed the benefits of an enhanced recovery protocol even for CD patients, which should ideally include, for this specific subgroup of surgical patients, satisfactory pre-operative anemia and malnutrition optimization and adequate evaluation by the inflammatory

bowel disease (IBD) and stoma teams after operation and before discharge.

In conclusion, an enhanced postoperative program optimizes recovery even in CD patients, boosting the already favorable outcomes obtained by minimally invasive laparoscopic surgery and minimizing the physiological surgical stress after a conventional open procedure, and it should always be adopted when the patient, surgeon and IBD team are compliant.

Strengths and limitations

This review provides the reader with an updated, accurate and comprehensive analysis of all possible current applications of minimally invasive surgery for the treatment of CD, describing the logical and chronological evolution of each technique in the context of different CD scenarios and emphasizing the main advantages with respect to traditional surgery.

The main limitation of this study is that, for its narrative nature, it does not include a systematic review of the literature.

Conclusions

Minimally invasive surgery has several postoperative advantages over conventional open surgery, such as reduced postoperative pain, shorter hospital stay, faster return to normal activity and diet, and improved cosmetic results.

Surgical interventions for CD do not represent an exception to this trend. Indeed, laparoscopic ileocolic resection is now considered the “gold standard” approach for the uncomplicated ileocecal disease, but also for the complex penetrating and recurrent disease, although adequate surgical expertise is required to face these more challenging scenarios.

With the worldwide spread of robotic surgery, it is now possible to safely and efficaciously perform robotic-assisted resections for CD, with confirmed advantages over conventional open procedures. However, the lack of evidence of the actual benefits compared to laparoscopic surgery, the greater costs and the longer operating times still prevent the widespread adoption of this minimally invasive strategy in daily practice.

A minimally invasive approach to a surgical IBD patient also involves preoperative patient optimization and enhanced recovery programs after surgery, which further improve the outcomes of laparoscopic procedures and are

easily and successfully adopted for the young and generally compliant population of CD patients.

In conclusion, a multidisciplinary board, a minimally invasive surgical approach, and adequate perioperative management are now the optimum of care for CD patients, where disease control, functional outcomes and quality of life are equally pivotal more than in other patient categories.

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