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RESEARCH

Laparoscopic and robotic intracorporeal resection and end-to-end anastomosis in left colectomy: a prospective cohort study — stage 2a IDEAL framework for evaluating surgical innovation

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Abstract
Purpose To analyze the safety and feasibility of intracorporeal resection and anastomosis in upper rectum, sigmoid, and left colon surgery, via both laparoscopic and robotic approaches. The secondary aim was to assess possible short-term differences between laparoscopic versus robotic surgery.
Methods A prospective observational cohort study according to IDEAL framework exploration and assessment stage (Development, stage 2a), evaluating and comparing the laparoscopic approach and the robotic approach in left colon, sigmoid, and upper rectum surgery with intracorporeal resection and end-to-end anastomosis. Demographic, preoperative, surgical, and postoperative variables of patients undergoing laparoscopic and robotic surgery are described and compared according to the surgical technique used.
Results Between May 2020 and March 2022, seventy-nine patients were consecutively included in the study, 41 operated via laparoscopy (laparoscopic left colectomy: LLC) and 38 by robotic surgery (robotic left colectomy: RLC). There were no statistically significant differences between the two groups in terms of demographic variables. In surgical variables, the median surgical times differed significantly: 198 min (SD 48 min) for LLC vs. 246 min (SD 72 min) for RLC ($p=0.01$, 95% CI: −75.2 to −20.5)). The only significant difference regarding postoperative complications was a higher degree of relevant morbidity in the LLC (Clavien-Dindo > II (14.6% vs. 0%, $p=0.03$) and Comprehensive Complication Index (IQR 22 vs. IQR 0, $p=0.03$). The pathological results were similar in both approaches.
Conclusion Laparoscopic and robotic intracorporeal resection and anastomosis are feasible and safe, and obtain similar surgical, postoperative, and pathological results than described in literature. However, morbidity seems to be higher in LLC group with fewer relevant postoperative complications. The results of this study enable us to proceed to stage 2b of the IDEAL framework.
Clinical trial registrations The study is registered in Clinical trials with the registration code NCT0445693.

Keywords Intracorporeal anastomosis · Left intracorporeal anastomosis · Minimally invasive left colon surgery · “Don’t touch the bowel” technique

Introduction

Currently, surgery remains the only curative treatment for colorectal cancer, in both early and advanced stages [1]. In recent decades, the minimally invasive approach has shown its benefits over open surgery, especially in terms of post-operative recovery (less postoperative pain, shorter hospital stay, and fewer postoperative complications), and achieves similar oncological results (Lacy et al. [2], Bonjer et al. [3]). Therefore, it is currently the approach of choice [4, 5].

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Nonetheless, laparoscopic surgery presents several limitations, such as the restricted movement of the instruments, which complicates the approach to the pelvis and makes the performance of intracorporeal sutures difficult. In the last decade, the introduction of robotic surgery in this setting has revolutionized minimally invasive surgery, providing clear advantages for the surgeon such as a three-dimensional view, image magnification, and greater freedom of movement of the instruments. This technique optimizes our ability to maneuver inside the surgical field and increases our precision, thus overcoming many of the limitations of laparoscopy just mentioned [6–8].

In recent years, the performance of intracorporeal anastomosis in right colon surgery has been shown to improve results, with lower rates of organ-space infection, less postoperative pain, earlier recovery, and a shorter hospital stay [7, 8].

In the standard laparoscopic approach to the left colon, sigmoid, and rectum, the specimen is extracted through an accessory incision made for its resection and for the insertion of the anvil of the circular stapler. This maneuver may cause tension in the mesocolon, and in certain patients (for example, those with vascular disease, short mesocolon, or obesity), the extraction can be extremely difficult; the tension can lead to a traumatic injury to the marginal vessels and restrict the vascular supply to the anastomosis, thus increasing the risk of anastomotic leakage due to ischemia.

There are few reports in the literature of intracorporeal resection and anastomosis in surgery of the left colon and sigmoid. In recent years, the techniques that have been described in both laparoscopic and robotic surgery include the performance of an intracorporeal side-to-side anastomosis by means of double stapling with an endostapler, like in right hemicolectomy, or the side-to-end "Baker" anastomosis with good short- and long-term results [9–14]. Despite this, these types of anastomoses are not comparable to the extracorporeal standard technique, end-to-end mechanical anastomosis, which has the lowest rate of complications and best functionality [15, 16].

Currently, there is no clear evidence of superiority of intracorporeal anastomosis vs. extracorporeal in left colon surgery, due to lack of randomized trials and high heterogenity of data.

In this study, we present the experience with the usual end-to-end anastomosis for extracorporeal procedure but in the intracorporeal way.

Our team has extensive experience in performing intracorporeal anastomoses in surgery for cancer of the rectum and right colon [10, 11]. In the last year, we have applied this experience to the surgery of the left colon, sigmoid, and upper rectum, by performing intracorporeal end-to-end anastomosis without the need for any handling of the specimen [12, 13]. In principle, this technique was a surgical adaptation to the situation caused by the COVID-19 pandemic, to follow some of the recommendations like the performance of laparoscopic procedures [17] with minimal evacuation of gas and exteriorization of the specimen, and intracorporeal intestinal anastomoses, but once its benefits became clear, we incorporated it as a technique under development within the IDEAL framework [18] and published an initial report describing the technical details and our first series of cases. This study corresponded to stage 1 of the IDEAL framework (Idea) [19].

The Idea, Development, Exploration, Assessment, Long-term (IDEAL) study framework [20] was developed to establish the steps to follow in surgical research. It describes 5 stages of evolution in surgical innovation and systematically, progressively increases the level of evidence from the starting idea to real practice. In IDEAL framework 2a stage, the aim is to develop the stage I idea, proof its safety and efficacy, and prepare for a definitive evaluation at the next stage.

The main objective of the present study is to develop stage 2a of the IDEAL framework (Development) [21] in the intracorporeal resection and anastomosis of the left colectomy, evaluate its safety and efficacy, and determine if the technique can be performed with both approaches with safety in terms of morbidity and mortality.

To do this, we used the Clavien-Dindo scale as the primary variable to evaluate morbidity, as well as the Clavien-Dindo scale $\geq$ II to evaluate relevant morbidity.

The secondary objective is to assess whether there are differences in surgical variables and postoperative and pathological complications between the two cohorts undergoing either laparoscopic or robotic surgery.

Method

Study design

Prospective observational cohort study of left colon, sigmoid, and upper rectum resection surgery and intracorporeal end-to-end anastomosis using laparoscopic (LLC) and robotic (RLC) approaches.

Comparative study between both approaches in terms of morbidity and mortality.

Patients and setting. Elective criteria

Inclusion criteria Patients over 18 years of age diagnosed with pathology of the descending colon, sigmoid colon, and upper third of the rectum above the peritoneal reflection, who underwent a left colectomy, sigmoidectomy, or upper anterior resection, with resection of the inferior mesenteric vessels and preservation of the middle cholic artery, both benign and malignant (any tumoral stage with curative

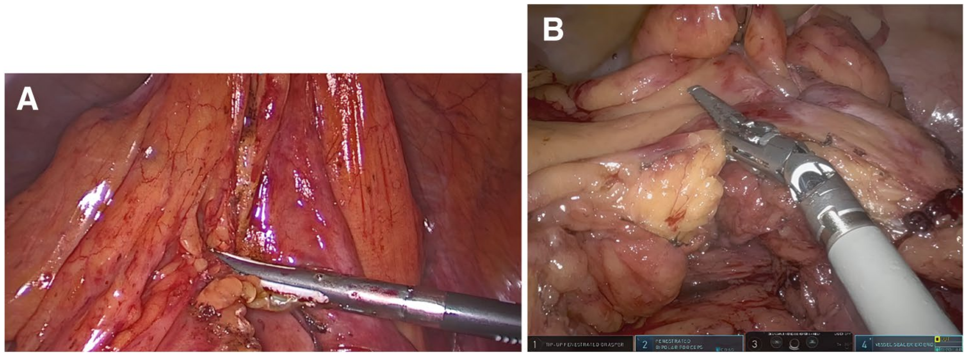

Fig. 1 Exposure of the mesocolon at the level of the resection area. **A** Laparoscopic. **B** Robotic

intention treatment) allowing a minimally invasive laparoscopic or robotic approach; provision of consent to undergo the procedure. All patients diagnosed with cancer were evaluated by the multidisciplinary colorectal tumor committee at our center. The therapeutic strategy was determined in accordance with international colon cancer protocols [22].

Exclusion criteria Emergency surgery, other tumor locations, synchronous tumors, multivisceral resections, suboptimal nutritional study (preoperative albumin $\leq$ 3.4 g/dl); refusal to undergo the surgical procedure, active pregnancy, liver cirrhosis, kidney failure treated with dialysis or pulmonary disease that precluded the creation of the pneumoperitoneum.

We included the patients included in the prior study, excluding the splenic flexure resections.

Preoperative preparation, surgical technique, and postoperative evolution

The local Institutional Ethics Committee approved the use of the intracorporeal technique for the treatment of tumors and diverticular disease of the left colon, sigmoid, and upper third of the rectum (CEIC 2020/679). The study complied with the criteria of the Declaration of Helsinki. The STROBE guidelines for observational studies were followed [23].

Informed consent was obtained from the patients after an explanation of the risks and benefits of the procedure. All patients who met the selection criteria were operated upon via laparoscopic or robotic approach, depending on availability. All surgical procedures were performed by the colorectal surgery team at Parc Taulí University Hospital, who have extensive experience in minimally invasive colorectal surgery including 7 surgeons. All patients complied with the center's prehabilitation program and underwent antegrade mechanical preparation. They along with oral antibiotics of erythromycin 1 g and neomycin 1 g (3 doses the day before surgery) antibiotic prophylaxis (amoxicillin-clavulanate Ac 2 g/ev or in the case of allergy metronidazole 1 g/ev and gentamicin 3–5 mg/kg/ev) during anesthetic induction and thromboembolic prophylaxis (enoxaparin 40 mg administered subcutaneously) in accordance with the institutional protocol. Also in accordance with our hospital's protocols for the COVID19 pandemic since April 2020 all prospective surgical patients underwent a COVID19 PCR test and a chest CT in the 48 h prior to surgery and only those with normal results were operated.

All oncological surgeries were performed following current guidelines and established oncological criteria [22].

The main stages of intracorporeal resection and anastomosis in the left colectomy, "a don't touch the bowel technique," have been described before [12, 13]. These stages apply to both LLC and RLC:

(1) Intracorporeal resection (Fig. 1 A–B). First, we performed a standardized high ligation of the inferior mesenteric artery and a standardized splenic flexure mobilization with IMV dissection. Over the proximal mesocolon, the origin of the inferior mesenteric vessels is taken as a reference, and the mesocolon is marked and sectioned intracorporeally (Fig. 1A). Next, we mark the area where the proximal section of the colon will be performed.
(2) Preparation of the anvil of the circular mechanical suture, and its introduction in the proximal colon (Fig. 2 A–B). A 29-mm curved circular stapler (B. Braun, Melsungen, Germany) is used. The anvil tip is mounted together with the anvil head. On this device, a 0 Prolene® monofilament suture is performed, with multiple knots to aid its manipulation, of about 7–10 cm in length so that it can be pulled through the staple line of the section of the colon. To introduce the anvil in the proximal colon, a colotomy is performed some 2–3 cm distal to the colon section mark. The anvil head is inserted in its entirety inside the colon, allowing the monofilament to exit through the colotomy. After the complete insertion of the anvil head

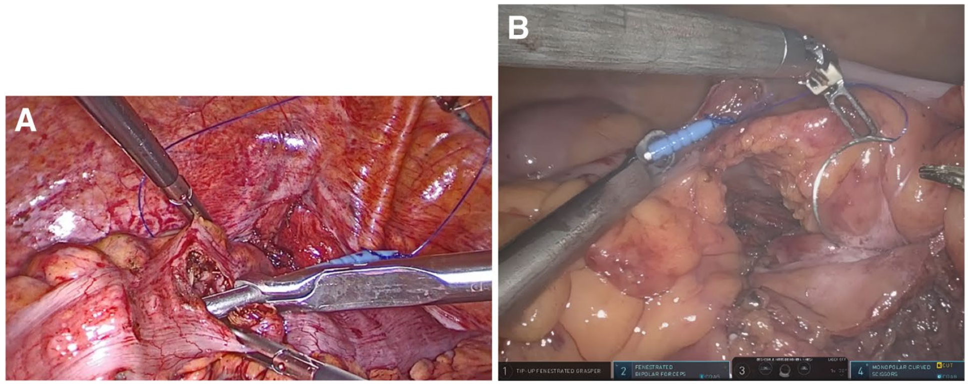

Fig. 2 The anvil head inserted entirely inside the colon, allowing the monofilament to exit through the colotomy. **A** Laparoscopic. **B** Robotic

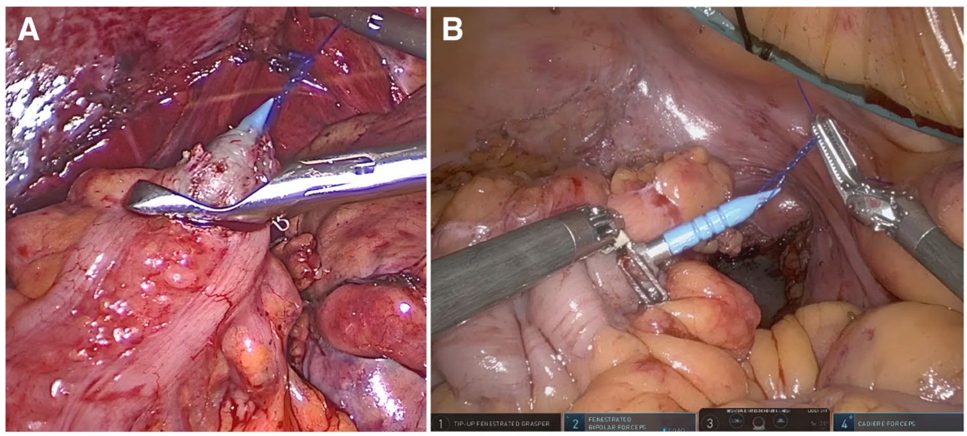

Fig. 3 Traction from the monofilament, with the exit of the anvil through the staple line. **A** Laparoscopic. **B** Robotic

beyond the section mark, the ECHELON FLEX™ ENDOPATH®, 1.5-mm staple height and 60-mm blue reload, is applied.

(3) Extraction of the anvil through the mechanical suture line of the colon (Fig. 3 A–B), extraction of the anvil tip (Fig. 4 A–B) and preparation of the proximal end of the anastomosis using a purse-string around the anvil.

(4) Introduction of the specimen in a plastic endobag (Applied Medical, Inzii 12/15 mm).

(5) A stapled end-to-end anastomosis is performed in accordance with the standard technique, checking the integrity of the anastomotic rings and the intraoperative air testing of the anastomoses.

(6) The specimen is extracted through a 3–5-cm mini-laparotomy adapted to the size of the tumor, inside a plastic bag (Applied Medical, Inzii 12/15 mm) protected with a dual-ring retractor (Alexis O Wound Protector C8401). The mini-laparotomy can be performed anywhere in the abdominal wall.

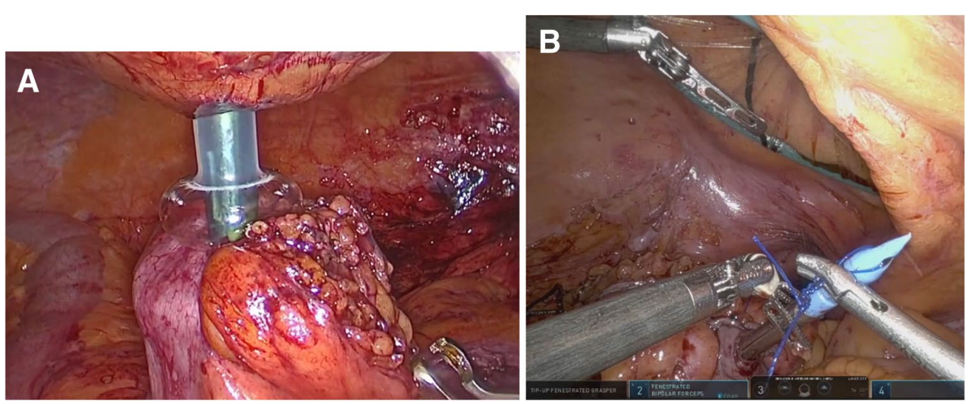

Fig. 4 Exit of the anvil. **A** Laparoscopic. **B** Robotic

Study variables Epidemiological: age and sex. Preoperative: ASA (American Society of Anesthesiologists) score ≥ III, body mass index (BMI), main diagnosis.

Surgical: type of surgery, surgical time, intraoperative complications, and conversion to surgery.

Postoperative variables at 30 days. Overall morbidity, Clavien-Dindo morbidity relevant morbidity (Clavien-Dindo > II) Comprehensive Complication Index (CCI) surgical site infection (SSI — incisional and organ-space)**anastomotic leak (AL),** reintervention due to AL, nosocomial infection, surgical and non-surgical complications, hospital stay, reoperation, and postoperative mortality. Pathological: pT, pN, nodes found and percentage of specimens with more than 12 nodes [22].

Definition of the study variables

Conversion to open surgery was considered if a midline laparotomy was performed or a Pfannenstiel incision greater than 10 cm was necessary. Anastomotic leak was defined in accordance with Peel et al. [24], surgical site infection according to the Center for Disease Control (CDC) National Surveillance System for Nosocomial Infections [25], and intraoperative complications were defined as any unexpected adverse surgical event during surgery.

Statistical study

The SPSS program version 26 was used. The prospective data collection permitted an analysis without the presence of missing values. In the description of the quantitative variables, the values of the mean and standard deviation were given, or the medians and interquartile range when the normality conditions were not met. The categorical variables were described in absolute numbers and percentages. The univariate statistical analysis of the quantitative variables, with independent groups, was carried out using the Student's *T*-test, provided its conditions of application were met otherwise, the Mann Whitney *U* or the Kruskal–Wallis test was applied. For categorical variables, Pearson's X^2 test or Fisher's exact test was used, depending on the conditions. A p value < 0.05 was considered statistically significant, with a confidence interval of 95%.

Results

From May 2020 to March 2022, 79 patients undergoing surgery for the left colon, sigmoid, or upper third of the rectum were included in the study, with intracorporeal resection and end-to-end anastomosis. The approach was laparoscopic in 41 patients (laparoscopic left colectomy: LLC) and robotic in 38 (robotic left colectomy: RLC).

Table 1 displays the patients' demographic and surgical variables. No significant differences between techniques were found in terms of age, BMI, or sex. The principal diagnosis was neoplasia in 68 (86.1%) of the patients, without differences between the groups (the others, nine patients had a chronic diverticulitis, and two patients had a colonic volvulus). Thirty-six of those oncologic patients undergoing LLC (87.8%) and thirty-two of those undergoing RLC (84.2%). Thirty-three patients (46.5%) were classified as complex according to the ASA scale (ASA score III or higher), with no statistically significant differences between the groups. The most frequent surgical technique was sigmoidectomy, with similar high anterior resection and left colectomy, distributed similarly between the groups. The mean surgical time was 213 min (SD 90 min); it was significantly shorter in LLC at 198 min vs. 246 min in RLC ($p = 0.001$, 95% CI: − 75.2 to − 20.5). Three intraoperative complications were recorded (4.2%) with no differences between the groups (5.3% in LLC vs. 3% in RLC). All of them were failures of the air leak test and all in sigmoidectomies and were solved with reinforcement of the anastomosis with single stitches. Conversion to open surgery was not required in any of the cases.

Table 2 displays the morbidity and mortality variables 30 days after surgery. Sixteen patients (20.3%) presented morbidity, 12 (29.3%) in the LLC group and four (10.5%) in the RLC group, not clearly statistically significant ($p = 0.05$, 95% CI: 35.8 to 1.7). Regarding the Clavien-Dindo Classification, there were no statistically significant differences between the groups, although only the LLC presented relevant morbidity (Clavien-Dindo greater than II) (14.6% vs. 0% in the RLC group) and in the CCI ($p = 0.003$). As for surgical site infection (incisional and organ/space), nosocomial infection, surgical and non-surgical complications, hospital readmission, overall mortality, hospital stay, and surgical reintervention, no statistically significant differences were found between the groups, although the scores tended to be lower in the RLC group. Anastomotic leak occurred in two patients (2.5%), both in the LLC group and both in the sigmoidectomy group; one of them required surgical treatment. There were no cases in robotic approach group. Despite this, there were no statistically significant differences between the two groups. Mean hospital stay was 3 days in both groups. Only one patient died during the postoperative period. He was reoperated by an inadvertent intestinal perforation but died due to decompensation of his previous medical pathology exacerbated by surgical stress and complex postoperative. Four patients (5.6%) required reoperation, all of them in the LLC group (10.5%): the patient just mentioned, one due to anastomotic leak, one due to bleeding from the Pfannenstiel wound, and the last one due to appearance of hernia at laparoscopic trocar incision sites.

Table 1 Patients' characteristics and perioperative data

Characteristic		All patients ($n=79$) (%)	Laparoscopic ($n=41$) (%)	Robotic ($n=38$) (%)	p value Difference (95% CI)
Sex	Women	31 (39.2)	16 (39)	15 (39.5)	0.58
	Men	48 (60.8)	25 (61)	23 (60.5)	0.45 (22 to −21.10)
Age, median (IQR) years		67 (20)	70 (18)	65.5 (22)	0.44
BMI, median (IQR)		26.9 (8.5)	26.8 (6.6)	27.4 (10)	0.59
Principal Diagnosis	Neoplasia	68 (86.1)	36 (87.8)	32 (84.2)	0.89
	Diverticular disease	9 (11.4)	4 (9.8)	5 (11.4)	
	Volvulus	2 (2.5)	1 (2.4)	1 (2.6)	
ASA score	I	13 (16.5)	4 (9.8)	9 (23.7)	0.23
	II	33 (41.8)	21 (51.2)	12 (31.6)	
	III	31 (39.2)	15 (36.6)	16 (42.1)	
	IV	2 (2.5)	1 (2.4)	1 (2.6)	
ASA score ≥ III		33 (41.8)	16 (39)	17 (44.7)	0.39 −5.7 (16.3 to −27.5)
Surgical Technique	Left colectomy	22 (27.8)	10 (24.4)	12 (31.6)	0.28
	Sigmoidectomy	36 (45.6)	17 (41.5)	19 (50)	
	High anterior resection	21 (26.6)	14 (34.1)	7 (18.4)	
Surgical time, mean (range, SD), min		213 (120–425, 90)	198 (120–320, 48)	246 (131–425, 72)	0.01 (−75.2 to −20.5)
Intraoperative complications		3 (4.2)	2 (5.3)	1 (3)	1 2.3 (11.4 to −7)
Conversion surgery to open		0	0	0	1

IQR interquartile range, *SD* standard deviation.

Table 3 displays the pathological variables of patients diagnosed with cancer. There were no statistically significant differences in the tumor staging between the two groups ($p=0.79$), or between rates of T3 and T4 ($p=1$, 95% CI 18.7 to −22.2). Regarding lymphadenectomy, a mean of 19 nodes was removed in the LLC group vs. 13 for the RLC group.

Discussion

In recent years, multiple studies have demonstrated the efficacy and safety of laparoscopic surgery to treat colorectal cancer and other pathologies, as well as its advantages over open surgery in many aspects such as hospital stay and postoperative pain. For these reasons, it is now the approach of choice in colorectal cancer surgery [2, 3]. The evolution of laparoscopy towards less invasive techniques such as intracorporeal resection and anastomosis has reduced organ-space infection and has improved patient recovery. In the case of scheduled right hemicolectomy surgery, performing intracorporeal ileocolic anastomosis has proven to be an effective procedure that reduces postoperative pain, hospital stay, and postoperative morbidity [26, 27].

As we have reported before intracorporeal resection of the specimen and mechanical end-to-end anastomosis without the need for extraction — the "don't touch the bowel technique" — offers multiple advantages such as the avoidance of excessive manipulation the reduction in the tension of the mesocolon caused by its exteriorization and on some occasions the avoidance of the mobilization of the splenic flexure. It also allows surgeons the freedom to choose the type of accessory incision for the extraction of the specimen. This advantage is especially important in morbidly obese patients with a large infraumbilical adipose panniculus. This technique allows us to avoid Pfannenstiel incision which despite being the type of incision with the lowest rate of eventration and postoperative pain may not be the best option. Specifically in this type of patients a supraumbilical incision where in obese patients there is less adipose tissue will allow us to make smaller incisions and possibly lower rate of complications related to the wound [28, 29].

There are few papers in the literature describing intracorporeal anastomosis techniques with good results. In recent years, the intracorporeal techniques described in the left colectomy have involved intracorporeal side-to-side anastomosis using an endostapler, a procedure like the one performed in the right hemicolectomy, with good short- and long-term results. However, it requires the mobilization of the splenic flexure to avoid tension on the anastomosis, by placing one segment next to the other as Ceccarelli et al. [9] showed us. Another intracorporeal technique described is mechanical side-to-end anastomosis

Table 2 Thirty-day postoperative morbidity-mortality

Characteristic		All patients ($n=79$) (%)	Laparoscopic ($n=41$) (%)	Robotic ($n=38$) (%)	*p* value Difference (95% CI)
Overall morbidity		16 (20.3)	12 (29.3)	4 (10.5)	0.05 18.7 (35.8 to 1.7)
Clavien-Dindo Classification (Cl-D)	0	63 (77.5)	29 (70.7)	34 (89.5)	0.19
	I	1 (1.3)	1 (2.4)	0	
	II	9 (11.4)	5 (12.2)	4 (10.5)	
	IIIa	1 (1.3)	1 (2.4)	0	
	IIIb	4 (5.1)	4 (9.8)	0	
	IVa	0	0	0	
	IVb	0	0	0	
	V	1 (1.3)	1 (2.4)	0	
Relevant morbidity (Cl–D > II)		6 (7.6)	6 (14.6)	0	0.03 14.6 (25.5 to 3.8)
Comprehensive Complication Index (CCI) score, median (IQR)		0 (0)	0 (22)	0 (0)	0.03
Surgical site infection (SSI)		5 (6.3)	4 (9.8)	1 (2.6)	0.36 7.1 (17.5 to − 3.3)
Incisional-SSI		2 (2.6)	1 (2.4)	1 (2.6)	1 − 0.2 (6.8 to − 7.1)
Organ/space-SSI		4 (5.1)	4 (9.8)	0	0.12 9.8 (18.9 to 0.7)
Anastomotic leak		2 (2.5)	2 (4.9)	0	0.5 4.9 (11.5 to − 1.7)
Surgical anastomotic leak		1 (1.3)	1 (2.4)	0	1 2.4 (7.2 to − 2.3)
Nosocomial infection		7 (8.9)	6 (14.6)	1 (2.6)	0.11 12 (24 to − 0.1)
Surgical complications		9 (11.4)	6 (14.6)	3 (7.9)	0.5 6.7 (20.1 to − 7.1)
Non-surgical complications		3 (3.8)	2 (4.9)	2 (2.6)	1 − 0.4 (9.3 to − 10.1)
Hospital readmission		1 (1.3)	0	1 (2.6)	0.5 − 2.6 (2.5 to − 7.7)
Overall mortality		1 (1.3)	1 (2.4)	0	1 2.4 (7.2 to − 2.3)
Surgery-related mortality		1 (1.3)	1 (2.4)	0	1 2.4 (7.2 to − 2.3)
Hospital stay, median (IQR, range) days		3 (1, 3–54)	3 (3, 3–54)	3 (1, 3–11)	0.37
Surgical reintervention		4 (5.1)	4 (9.8)	0	0.12 9.8 (18.8 to 0.7)

IQR interquartile range.

("Baker" type anastomosis) with extraction of the specimen through a colotomy at the distal end, described by Akamatsu et al. [14, 30]. End-to-end anastomosis was described by Ohmura Y. et al. with a hemi-hand-sewn technique [31]. In robotic surgery, an intracorporeal side-to-side anastomosis of this kind has also been described in left colectomy by Benlice et al. [32].

Circular mechanical end-to-end colorectal anastomoses in the left colon appear to be the safest [15, 16]. The percentage of anastomotic leaks is around 7.5% [33]. Similarly, end-to-end anastomosis in surgery of the middle and lower rectum has been shown to achieve better results than side-to-end anastomosis [15, 16]. For this reason, we believe that intracorporeal end-to-end anastomosis is the best option.

Just as a new drug undergoes several phases of clinical trials, we believe that a new surgical innovation or a major modification of a surgical technique should go through a similar process of evaluation. This is the aim of the IDEAL framework [20]. Our first publication of the resection

Table 3 Neoplasia: surgical pathological outcomes

Characteristic		All patients (*n* = 73) (%)	Laparoscopic (*n* = 39) (%)	Robotic (*n* = 34) (%)	*p* value Difference (95% CI)
pT	pT0	3 (4.1)	2 (5.1)	1 (2.9)	0.79
	pT1	8 (11)	3 (7.7)	5 (14.7)	
	pT2	9 (12.3)	6 (15.4)	3 (8.8)	
	pT3	42 (57.5)	22 (56.4)	20 (58.8)	
	pT4	11 (15.1)	6 (15.4)	5 (14.7)	
pT3–4		53 (72.6)	28 (71.8)	25 (73.5)	1 − 1.7 (18.7 to − 22.2)
pN	pN0	46 (67.6)	23 (63.9)	23 (71.9)	0.7 − 1.2 (18.7 to − 22.2)
	pN1	11 (16.2)	6 (16.7)	5 (15.6)	
	pN2	11 (16.2)	7 (19.4)	4 (12.5)	
Overall lymph nodes found, median (IQR),		17 (11)	19 (13)	13 (7)	0.12

pT pathology tumor, *pN* pathology node, *IQR* interquartile range

technique and end-to-end anastomosis in the left colectomy represented part of stage 1 of the IDEAL project (i.e. the Idea stage). The aim of the present study was to develop the following stage stage 2a (Development) by designing a prospective single-center cohort study [21].

According to results obtained, we can affirm that the realization of a fully intracorporeal mechanical end-to-end anastomosis, both by laparoscopic and robotic approach, is a safe and feasible technique, with results like the series described in the literature with extracorporeal anastomosis with the same approaches. It opens the door in research and proposes that this technique could be compared with the standard technique in future studies, to evaluate its possible benefits, especially in obese, vascular disease, and short-mesocolon patients, and as Ohmura Y. et al. propose, it could eliminate unnecessary splenic flexure mobilization in left-side colectomies.

Despite having standard results, differences in relevant morbidity between the two approaches are statistically significant as well as surgical time.

The results of this study of intracorporeal surgery compare favorably with those of one of the most extensive reports to date of laparoscopic and robotic extracorporeal surgery of the left colon, published by Mlambo et al. [34]. In their study, the main variables were hospital stay (laparoscopy: 5 days, robotics: 4 days), surgical time (laparoscopy: 256 min, robotics: 328 min), conversion to open surgery (laparoscopy: 13%, robotics: 7%), morbidity at 30 days (laparoscopy: 25.2%, robotics: 21.8%), anastomotic leak (laparoscopy: 7.6, robotics: 5.5%), and reoperation (laparoscopy: 6%, robotics: 5.2%). Our results using the intracorporeal technique were similar, or even better (Tables 1 and 2). In accordance with Mlambo et al., we also found a trend towards better results with robotic surgery.

This standardized intracorporeal procedure does not increase the technical difficulty. The surgical times in our series were within the usual range in standard laparoscopic surgery [34], although, as in other publications, they were longer in robotic surgery than in laparoscopic surgery [6, 7, 35]. This is mainly due to the time needed for docking the robotic equipment.

Obviously, the fact that the team training in robotic surgery has been done after their training in laparoscopic surgery, the difference in surgical time may be partially due to it. Despite this, the surgical time in the robotic approach group is similar to what has been described in the literature.

It should be noted that this data can be especially relevant in environments with significant care pressure. However, once the systematization of robotic surgery and technique is normalized, this difference can be minimized to be irrelevant from a practical point of view.

In the postoperative results, statistically significant differences were only found between the LLC and RLC techniques in terms of relevant morbidity and in Comprehensive Complication Index score, with higher morbidity in the laparoscopic approach. After the analysis of the results, this is due to a higher rate of IIIa and IIIb complications (surgical site infection and anastomotic dehiscence that required treatment under local anesthesia and surgical reoperation under general anesthesia). Both data separately do not imply statistical significance, possibly due to a small sample size, but in combination, which is clinically relevant.

More surgical reoperations were observed in the LLC group than in the RLC group, two of them due to adverse circumstances that may occur in laparoscopic or robotic surgery such as a tension hematoma of the Pfannenstiel incision and umbilical port site hernia.

Although this result is statistically significant, we cannot clearly determine that it is due to the technical benefits of robotic surgery. These are two complications related to surgical incisions, performed in the same way in both approaches. The other two cases could be due to the improvement in surgical precision that can avoid inadvertent injuries (inadvertent intestinal perforation), and greater degree of freedom of movement when performing our technique, but we cannot draw conclusions about the robotic surgery superiority from these only two cases.

About pathology results, the resections met oncological standards, with more than 90% of cases presenting more than 12 nodes, slightly higher in laparoscopic resections [22, 34]

The main limitation of the study is its non-randomized, observational design, no sample size has been calculated because there is no previous data to calculate, and the design of the study was conducted to a stage 2a IDEAL framework. However, the patients were operated consecutively and followed prospectively.

The patients were operated sequentially. First, the technique was developed with a laparoscopic approach to verify safety and feasibility in the pilot study, and the technique was standardized by this approach, including our firsts patients in the present study.

Subsequently, we completed the learning curve for this technique with a robotic approach to avoid biases, and, after that, patients with both approaches were included in an overlapping way, depending on the availability of the material (given that as in many centers, we share the robot with other specialties such as urology or gynecology, and we do not always have the robotic approach available).

This entails a bias in the analysis of the data obtained, which, despite extensive laparoscopic experience of the surgical team, can alter the results.

Another point of discussion is the inclusion and exclusion criteria. Although this technique can be applied in patients who include exclusion criteria such as patients on hemodialysis or palliative surgeries, it is a technical evaluation study, and we wanted to reduce the confounding factors that may occur including patients with synchronous tumors (which may require extended surgeries), previous colon surgeries (who may have modified colonic vascularization), multivisceral resections, or patients with complex medical pathology.

Another point that may be controversial is the heterogenicity of the patients included in the study, in terms of diagnosis. We included neoplasia, diverticular disease, and colonic volvulus patients in the study.

Patients with diverticular disease usually have greater difficulty in dissection, retraction of the meso and chronic inflammation, which can increase tension and decrease the length of the colon for the realization of anastomosis, as well as hinder the technique when introducing the anvil head. Another point of discusion in cases of diverticular disease is the performance of high ligation or low ligation. In cases of benign pathology, the evidence is weak on whether high ligation of AMI provides any benefits or if it is associated with further complications. Despite this, the literature seems to show that there are no statistically significant differences between dissect or not the AMI in cases of diverticular disease [36].

In case of volvulus, the great dilation of the colon and its diameter can make it difficult to perform the anastomosis, as well as the manipulation by minimally invasive approach. In the patients included with these two diagnoses, there were no differences with oncologic patients in terms of results.

One of the controversial points in the study is the realization of the splenic flexure mobilization in all patients. In our case, we systematically perform it from medial to lateral always following the same landmarks, which greatly reduces the risk of complications related to it.

The systematic performance of this surgical step has been the subject of discussion in numerous publications and literature review confirmed the absence of agreement with contradictory results and opinions. We have not observed a greater number of complications related to the mobilization of the splenic flexure and our results are similar to the data published in the literature in relation to peri- and postoperative complications [37, 38].

This study has been carried out in a center with high experience in minimally invasive surgery, with more than 150 laparoscopic or robotic procedures per year in colorectal surgery. Therefore, the data cannot be compared with inexperienced centers. In addition, the availability of the robot is limited to the economic resources of each center, so currently only highly specialized centers can have it. As existing patents are eliminated, robotic surgery can be introduced in more centers, reducing the cost per procedure.

About medical expense, more studies are needed to demonstrate whether there actually are significant differences between the two approaches and whether the benefits can outweigh the cost difference, and if we should reserve the use of the robot for those patients who can really benefit from this approach.

Finally, one of the most important points to discuss and analyze in the future will be the determination of whether these good results are maintained in the medium and long term, and to determine if there are long-term differences in terms of the rate of recurrence or recurrence locally or at a distance, as well as differences in overall survival.

Conclusion

The overall results of the study show that intracorporeal resection and end-to-end anastomosis performed via either laparoscopic or robotic approach are a safe and viable technique. The results are comparable with those published in the literature in intracorporeal anastomosis and extracorporeal anastomosis, in terms of perioperative variables, postoperative complications, and pathological results.

The results of the study allow us to proceed to the following stage of the IDEAL framework, stage 2b (Exploration), moving on from observational to comparative evaluation [20].

Next step in our study is the development of a comparative study between the technique of resection and intracorporeal anastomosis with the conventional extracorporeal technique, within phase 2b of the IDEAL framework.

The objective is to demonstrate that the technique of resection and intracorporeal anastomosis is non-inferior to the standard conventional extracorporeal technique, and to determine in which patients can provide greater benefits, such as in patients with high BMI or tumor locations in descending colon.

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Author contribution XSA, LML, and IGT wrote and edited the paper. All authors (XSA, LML, IGT, APL, AS, AGN, OPP, AT, SNS) have reviewed the paper, revising it critically for intellectual content. Each author has participated sufficiently in the work of reviewing and approving the study as written.

Availability of data and materials Not applicable.

Declarations

Ethics approval and consent to participate The study was approved by our center's local ethic committee (CEIC 2020/679).

All patients included in the study were informed of the surgical technique used as well as its risks and possible complications. They provided specific informed consent to undergo the surgery.

Consent for publication Not applicable

Competing interests The authors have no conflicts of interest to declare.

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