Completely intracorporeal anastomosis in robotic left colonic and rectal surgery: technique and 30-day outcomes

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Abstract

As robotic surgery continues to disseminate into the field of colon and rectal surgery, there is a growing interest in the utilization of intracorporeal anastomosis to potentially improve surgical outcomes. The purpose of this study was to compare feasibility, safety, and short-term outcomes of robotic sigmoid and low anterior resections performed with completely intracorporeal anastomosis (CICA) technique to the traditional extracorporeal assisted anastomosis (ECAA) technique. Consecutive series of patients who underwent elective robotic sigmoid or low anterior resections for benign or malignant disease utilizes either CICA or ECAA between August 2017 and November 2019. Surgical complications were assessed until 30 postoperative days and compared between the two groups. A total of 160 patients were identified; 73 (45.6%) in the CICA group and 87 (54.4%) in the ECAA group. Most of the procedures were performed for malignancy (76%). Estimated blood loss was lower in the CICA group (80.7 mL vs. 110.2 mL; $p=0.048$), while operative times were longer ($5.9 \pm$ SD hours vs. $4.9 \pm$ SD hours; $p < 0.001$). Overall conversion rate was 1.9%, with no conversions in the CICA group. Overall complications occurred in 54 patients (33.8%) with 13 (8.3%) representing major complications. There were no significant differences in 30 day outcomes between the two groups. This study demonstrates the feasibility and safety of robotic sigmoid and low anterior resections with CICA. Outcomes for robotic sigmoid and low anterior resections are encouraging regardless of anastomotic technique (CICA vs ECAA).

Keywords Colorectal surgery · Intracorporeal anastomosis · Robotic surgery · Extracorporeal anastomosis · Short-term outcomes

Introduction

The introduction of laparoscopic surgery facilitated the development of techniques such as a completely intracorporeal anastomosis (CICA). These completely intracorporeal techniques rapidly gained favor in bariatric surgery and have become the standard of care given the dramatic reduction in complications associated with wound infection, hernia, and prolonged length of stay [1]. These improved outcomes led to further expansion of such techniques into colon and rectal surgery.

Despite these data, uptake remains slow and the majority of laparoscopic right colectomies are still performed with an extracorporeal anastomosis. With the addition of robotic platforms, the construction of an intracorporeal anastomosis is gaining popularity as a feasible, safe, and effective alternative [2]. A recent meta-analysis suggested that the technique is associated with reduced short-term morbidity and decreased length of hospital stay [3]. Although some groups have suggested that CICA are safe for left-sided disease, the uptake and dissemination has been limited because of the technical limitations of laparoscopic surgery [4, 5].

The wristed action, advanced optics, and precision of robotic surgery have not only propagated intracorporeal anastomosis for right-sided resections [6], but has also allowed surgeons to revisit a completely intracorporeal anastomosis for the technically more challenging left-sided resections.

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This study set about to document our institution's technique for robotic completely intracorporeal anastomosis (CICA) for left-sided resections and present short-term outcomes compared to standard extracorporeal assisted anastomosis (ECAA).

Methods

Study population and outcomes

A retrospective cohort study was undertaken of all sequential patients who underwent elective robotic sigmoid or low anterior resection (LAR) with anastomosis for diverticular disease or cancer at our institution from August 2017 to November 2019.

Five board-certified colorectal surgeons with longstanding robotic experience undertook the standardized robotic procedures. Starting from August 2017 onward, two surgeons began to use a CICA as the technique of choice, while the others continued to use a ECAA technique. These differing techniques formed the basis of the cohort analysis.

Patient characteristics, anastomotic technique, operative data, and 30-day outcomes were obtained from a prospectively maintained institutional database. Demographic characteristics included age, gender, body mass index (BMI), and American Society of Anesthesiology (ASA) score. Surgical details included duration of operation, use of a diverting loop ileostomy, conversion to open surgery, and independent operative experience of the surgeon. Surgeons performing traditional ECAA had 11.6 years of independent operative experience on average, while surgeons performing CICA as the technique of choice had 3 years of independent operative experience. Perioperative care over the entire study period was standardized for all patients according to our Institutional Enhanced Recovery Pathway (ERP) [7].

Postoperative morbidity was defined as any complication occurring during the first 30 postoperative days, classified according to Clavien–Dindo and compared between the two groups [8]. Severe complications were defined as grade $\geq$ IIIb. Postoperative surgical complications were classified in five subgroups: ileus (defined as need for nasogastric tube reinsertion), small bowel obstruction (SBO) requiring surgical intervention, clinically or radiographically confirmed anastomotic leak, surgical site infection (SSI), and deep site infections (DSI). Pooled infection was defined as any type of infection occurring during the postoperative stay. Reoperation, readmission, and length of stay were assessed. To compute the time needed to perform CICA (starting with enterotomy until completion of colorectal anastomosis), a representative sample of 35 intraoperative video recordings was reviewed.

Surgical technique

All patients underwent robotic mobilization, high vessel ligation, and resection according to our institutionally standardized principles and approach [9]. Once the rectum is divided and adequate proximal colon length has been obtained, a robotic colorectal anastomosis is performed.

The gold-standard ECAA consisted of a Pfannenstiel incision with placement of a small Alexis™ (Applied Medical, Rancho Santa Margarita, CA) wound retractor. The stapled edge of the proximal colon is taken extracorporeally, with subsequent placement of the stapler's anvil using a purse-string; a 25 or a 28 mm Covidien 4.8 mm EEA stapler was selected based upon proximal colon diameter [9]. The proximal colon and anvil is then returned to the abdomen. The Alexis™ wound retractor is secured to allow restoration of pneumoperitoneum, and the anastomosis is performed under direct robotic or laparoscopic visualization. A leak test is performed by either rigid proctoscopy or flexible sigmoidoscopy.

In the CICA technique, a Pfannenstiel incision is made at the start of the case and secured with an Alexis™ wound retractor. This is done to optimize case workflow as it allows placement of the stapler's anvil through the Alexis while leaving the robot docked.

Once the anvil is placed, the anastomosis begins by placing a mark on the antimesenteric tinea 3 cm from the proximal transection point using the fenestrated bipolar as a guide—its jaws are 2 cm in length (Fig. 1a). A small full-thickness entry is made with the monopolar shears directly over the mark. A 3.5 cm colotomy is then made starting just distal to the planned proximal transection point (Fig. 1b). The head of the anvil is grasped with a large needle driver and placed through this colotomy allowing the tip of the anvil to pass through the defect created at the 3 cm mark (Fig. 1c). The Covidien EEA™ is preferred as the lower profile of the anvil head significantly improves control during placement. The colotomy is closed with a 2–0 V-Loc™ suture (Medtronic, Minneapolis, MN).

The proximal colon is then divided with the robotic SureForm™ 60 mm blue load stapler (Intuitive, Sunnyvale, CA) to include the colotomy and its closure in the resection (Fig. 1d). The specimen is placed in the right lower quadrant. The proximal colon is then brought into the pelvis and a stapled side-to-end anastomosis is performed: the vessel sealer is placed in arm 1 and utilized to elevate the anterior peritoneal reflection; the fenestrated bipolar is placed in arm 2 and utilized to grasp the smooth plastic portion of the anvil for alignment; and the tip-up grasper in arm 4 is utilized to connect the EEA stapler (Fig. 1e). The orientation of the anastomosis is maintained by holding the colonic staple line in a direct

Fig. 1 Steps of the complete intracorporeal anastomosis. **a** Marking the distance. **b** Colotomy. **c** Placing the anvil. **d** Resection. **e** Side-to-end anastomosis. **f** Maintaining the orientation of the anastomosis.

vertical orientation (Fig. 1f). A leak test is performed with a flexible sigmoidoscopy. The specimen is then extracted through the Pfannenstiel incision.

Statistical analysis

Patient characteristics are presented as frequencies and percentages for categorical data and mean with standard deviation for continuous data. Differences between the CICA and ECAA groups were examined using the χ^2 test for categorical data and Student's *t* test for continuous data. Differences for length of stay and operative time were analyzed using the Mann–Whitney *U* test because of non-normal distribution of the data. All statistical tests were two-sided and a level of ≤ 0.05 was used to indicate statistical significance. As both study groups were comparable, statistical matching was not necessary. Analysis was conducted using JMP® PRO Version 13.0. (SAS Institute Inc., Cary, NC).

Results

One hundred and sixty patients were included in the study. Of these, 73 (45.6%) patients underwent a CICA, while 87 (54.4%) patients had ECAA. One hundred and twenty-two patients (76.25%) had colorectal adenocarcinoma, 52 (71.2%) patients in the CICA group, and 70 (80.46%)

patients in the ECAA group ($p = 0.17$). Anterior resection for rectal cancer was performed in 98 (61.25%) patients.

Overall postoperative complication rate was 33.8%, with no difference between the two groups (35.6% for CICA group vs 32.2% for the ECAA group; $p = 0.65$). Major complications, minor complications, surgical site infections, postoperative ileus, anastomotic leak, need for reoperation, and need for readmission did not differ between the two groups (Table 1). Median length of stay was 4.5 (IQR 3.2) in the CICA group and 4.9 (6.1) days in the ECAA group, respectively ($p = 0.29$). Mean operative time was higher in patients with CICA compared to ECAA ($5.9 \text{ h} \pm 1.8$ vs $4.9 \text{ h} \pm 1.7$; $p < 0.001$). The difference in the mean operative time between obese and non-obese patients was higher in the ECAA group (0.8 h) compared to the CICA group (0.4 h) (Table 2). The average duration for CICA creation was 25 (SD) min.

Discussion

This paper outlines our institution's technique for complete intracorporeal anastomosis for robotic left-sided colorectal resections. Compared to the standard extracorporeal assisted anastomosis, the CICA technique showed no significant difference in terms of surgical short-term outcomes, reoperation rates, readmission rates, and length of stay. Specifically, both major and minor complications, surgical site infections,

Table 1 Outcomes

	All (<i>n</i> = 160)	CICA group (<i>n</i> = 73)	ECAA group (<i>n</i> = 87)	<i>p</i>
Any complication (I–V) (%)	54 (33.8)	26 (35.6)	28 (32.2)	0.65
Major complication (IIIb–V) (%)	13 (8.1)	5 (6.8)	8 (9.2)	0.59
Minor complication (I–IIIa) (%)	41 (25.6)	21 (28.8)	20 (23.0)	0.40
SSI (%)	9 (5.6)	4 (5.5)	5 (5.7)	0.94
DSI (%)	6 (3.8)	2 (2.7)	4 (4.6)	0.53
Ileus (%)	19 (11.9)	7 (9.6)	12 (13.8)	0.41
Anastomotic leak (%)	6 (3.8)	1 (1.4)	5 (5.7)	0.13
Pooled infection (%)	18 (11.3)	7 (9.6)	11 (12.6)	0.54
Reoperation (%)	6 (3.8)	1 (1.4)	5 (5.7)	0.13
Readmission (%)	18 (11.3)	7 (9.6)	11 (12.7)	0.55
Length of stay (days) (median, IQR)	4.7 (4.9)	4.5 (3.2)	4.9 (6.1)	0.29

Postoperative complication in patients with intracorporeal anastomosis (*n* = 73) and patients with extracorporeal anastomosis (*n* = 87)

SSI Surgical site infection, DSI Deep space infection, POD postoperative day

Bold characters indicate significant values (*p* < 0.05)

Table 2 Demographics and operative details

	All (<i>n</i> = 160)	CICA group (<i>n</i> = 73)	ECAA group (<i>n</i> = 87)	<i>p</i>
Age (years) (mean ± SD)	59.1 ± 10.1	59.1 ± 10.5	57.8 ± 12.1	0.49
Gender (male, %)	99 (61.9)	44 (44.5)	55 (55.5)	0.70
BMI (kg/m ²) (mean ± SD)	29 ± 6.8	28.9 ± 6.9	29.1 ± 6.7	0.92
ASA ≥ 3 (%)	69 (43.3)	34 (46.5)	35 (40.2)	0.45
Adenocarcinoma (%)	122 (76.3)	52 (71.2)	70 (80.46)	0.17
Diverticular disease (%)	38 (23.7)	21 (55.3)	17 (44.7)	0.17
Neoadjuvant chemo-radiotherapy (%)	55 (34.4)	23 (31.5)	32 (36.7)	0.48
Additional organ resection (%)	14 (8.7)	5 (6.8)	9 (10.3)	0.43
LAR (%)	69 (43.1)	28 (38.4)	41 (47.1)	0.38
TSMRE (%)	29 (18.1)	12 (16.4)	17 (19.5)	0.48
Height from ARJ > 5 cm (%)	67 (41.8)	28 (38.4)	39 (44.8)	0.94
Height from ARJ 1–5 cm (%)	31 (19.4)	11 (15.1)	20 (22.9)	0.42
Take down of the splenic flexure (%)	62 (38.75)	23 (37.10)	39 (62.90)	0.08
Diversion (%)	70 (43.7)	29 (39.7)	41 (47.3)	0.10
Conversion (%)	3 (1.9%)	0 (0.0)	3 (3.5)	0.36
OD (hours) (mean ± SD) overall	5.4 ± 1.8	5.9 ± 1.8	4.9 ± 1.7	< 0.001
OD (hours) (mean ± SD), BMI ≥ 30	5.7 ± 1.8	6.2 ± 1.7	5.3 ± 1.8	0.04
OD (hours) (mean ± SD), BMI < 30	5.1 ± 1.7	5.8 ± 1.9	4.5 ± 1.5	0.02

Baseline demographic and surgical parameters of patients with intracorporeal anastomosis (*n* = 73) and patients with extracorporeal anastomosis (*n* = 87)

BMI body mass index, ASA American Society of Anesthesiology Score, ARJ anorectal junction, LAR low anterior resection, TSMRE tumor specific mesorectal excision, OD operation duration

Bold characters indicate significant values (*p* < 0.05)

postoperative ileus, anastomotic leak, need for reoperation, and need for readmission did not differ between the two groups.

The suggested CICA technique appears to be feasible, safe, and effective for left-sided and rectal resections using

a robotic platform. The iteration of the technique described in this article was designed to be simple, reproducible, and teachable.

A meta-analysis from 2013 suggested that CICA for right-sided laparoscopic procedures results in improved

cosmesis and functional recovery, without increasing intra- and postoperative complications [10]. Two more recent meta-analyses conducted on both prospective and retrospective studies comparing the intracorporeal versus the extracorporeal performed anastomosis in laparoscopic right hemicolectomy confirmed these findings; laparoscopic CICA was not only associated with faster recovery but also with lesser anastomotic leakage, lesser surgical site infection, and with a lower risk of incisional hernia compared to the extracorporeal anastomosis group [3, 11]. Another meta-analysis comparing robotic right colectomy with laparoscopic right colectomy showed better results in respect of short-term outcomes for robotic surgery and the authors suggested that this could be explained by the more frequent use of intracorporeal anastomosis (ICA) within robotic procedures [12]. Moreover, a recently published randomized-controlled trial (RCT) found that intracorporeal anastomosis was associated with a shorter hospital stay and fewer short-term postoperative complications, such as the incidence of paralytic ileus, gastrointestinal bleeding, and grade I and II complications [13]. The CICA technique was adopted in our division with the logic that such benefits would be translatable to the robotic platform.

Although there is proven benefit for intracorporeal reconstruction compared to the standard ECAA [14], the technical complexity and difficulty of this technique for left colic and rectal laparoscopic resections have limited its spread over the last decade [4, 5]. The reason for this could be found in the physical limits of straight-lined instruments used in laparoscopic surgery, which prevented many surgeons from developing a reproducible and time-saving technique for the anvil placement. The robotic platform has allowed surgeons to overcome those limitations while maintaining the advantages of minimally invasive surgery. The three-dimensional vision, increased precision, and stable platform have been critical in the creation of a colorectal CICA according to this technique [15]. First, insertion of an anvil through the colotomy is easy and smooth, because the surgeons can apply adequate traction to the colon and move the anvil at the same time. Second, the hand-sewn suture of the colotomy is faster and does not require advanced skills compared to laparoscopic suturing.

Concerns have been raised about an increased risk of intraabdominal infections with CICA as a result of the colotomy for anvil placement. However, this study revealed no differences in terms of superficial or deep site infections between the two techniques. This is in line with several large retrospective series and prospective studies that have demonstrated no increase in wound infections or intraabdominal abscesses in laparoscopic right colectomy with intracorporeal anastomosis [16–18]. Although only small series and single institution studies have analyzed CICA for left-sided resections, the available data seemed to confirm our

findings, reporting comparable rates of wound complications as patients submitted to the conventional extracorporeal procedure [14, 19, 20]. The encouraging results of the elective left-sided intracorporeal anastomosis might be translated to the emergency surgery, as reported in a recent single-surgeon series in which primary intracorporeal anastomosis was safely and feasibly performed for left-sided colorectal resections in an acute setting [21]. Even in cases of perforated diverticulitis or obstructing left carcinoma, sigmoid resection can be safely and entirely performed laparoscopically [22, 23].

One significant difference in the technique is its side-to-end configuration. A side-to-end colorectal anastomosis has been shown to be as safe as an end-to-end anastomosis, with the potential of functional advantages [24–26]. In a recently published randomized trial comparing side-to-end and straight stapled colorectal anastomosis after low anterior resection, patients operated with the side-to-end reconstructive technique showed better outcomes in terms of quality of life, fecal incontinence, and number of bowel movements [27].

Another matter of concern is the potential risk of intraperitoneal dissemination and seeding of tumor cells associated with the CICA technique compared to the traditional ECAA. The full-thickness colotomy is made distal to the planned proximal transection point leading to temporary exposure of the colonic lumen to the abdominal cavity (Fig. 1b). Thus, a potentially higher risk of local recurrence related to the new anastomotic technique needs to be further evaluated. To our knowledge, no study has yet reported local recurrence rates of patients with rectal or sigmoid cancer undergoing CICA. This topic will be further evaluated in the present cohort after sufficient long-term follow-up is achieved.

Even though operative time was longer in the CICA group by an average of 1 h, the specific time for anastomosis creation averaged only 25 min. Thus, shorter operative times in the ECAA group may rather be related to increased experience of the surgeons than to significant delays due to anastomosis creation.

CICA may lead to further benefit among obese patients, given the added challenges of both visceral and subcutaneous adiposity during anvil placement and specimen. Indeed, the operative time among CICA operations seemed to be less influenced by patients' BMI compared to the standard ECAA procedures (Table 2). The extracorporeal technique may require additional colonic mobilization to allow safe extraction for anvil placement increasing the possibility of unintentional twisting or mesenteric stretching that can result in edema, bleeding, and ultimately delayed intestinal recovery. Our results showed 9.6% of ileus in the CICA group compared to 13.8% in the ECAA ($p=0.41$). This finding did not reach statistical significance which may be related to type II error, but it indicates a potential benefit of

the CICA technique in enhancing postoperative gastrointestinal recovery. Interestingly, CICA group showed a trend toward less need for splenic flexure mobilization than ECAA group (37.1% vs 62.9%, $p = 0.08$) suggesting another potential benefit of the intracorporeal technique, especially when it comes to patients with obesity.

This study is limited by its retrospective nature and its non-randomized design. Another limiting factor is the different surgical experience of involved surgeons. Both surgeons who implemented the CICA technique were less experienced than the surgeons who performed the ECAA anastomosis, potentially representing a negative selection bias when assessing safety and feasibility of the technique.

Furthermore, this pilot study is likely underpowered. The investigation would benefit from a larger cohort across multiple centers, before a randomized control trial comparing the two techniques.

In conclusion, this paper outlines a safe and feasible technique for complete intracorporeal anastomosis for sigmoid and rectal resections. Intraoperative and short-term postoperative outcomes are encouraging regardless of anastomotic technique.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s13304-021-01061-z>.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by PA, MAAEA, and KTB. The first draft of the manuscript was written by FG, PA, and MAAEA, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials Because of the sensitive nature of the data collected for this study, requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to the corresponding author.

Declarations

Conflict of interest No disclosures or conflicts of interest related to this project to declare.

Ethics approval This study was approved by the Institutional review board.

Consent to participate Informed consent to participate in the study was obtained from all the participants.

Consent for publication Informed consent for publication was obtained from all the participants.

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

References

1. Nguyen NT, Neuhaus AM, Ho HS et al (2001) A prospective evaluation of intracorporeal laparoscopic small bowel anastomosis during gastric bypass. *Obes Surg*. <https://doi.org/10.1381/096089201321577875>
2. Hanna MH, Hwang GS, Phelan MJ et al (2016) Laparoscopic right hemicolectomy: short- and long-term outcomes of intracorporeal versus extracorporeal anastomosis. *Surg Endosc* 30:3933–3942. <https://doi.org/10.1007/s00464-015-4704-x>
3. van Oostendorp S, Elfrink A, Borstlap W et al (2017) Intracorporeal versus extracorporeal anastomosis in right hemicolectomy: a systematic review and meta-analysis. *Surg Endosc*. <https://doi.org/10.1007/s00464-016-4982-y>
4. Akamatsu H, Omori T, Oyama T et al (2009) Totally laparoscopic sigmoid colectomy: a simple and safe technique for intracorporeal anastomosis. *Surg Endosc* 23:2605–2609. <https://doi.org/10.1007/s00464-009-0406-6>
5. Park JS, Choi GS, Kim HJ et al (2011) Natural orifice specimen extraction versus conventional laparoscopically assisted right hemicolectomy. *Br J Surg*. <https://doi.org/10.1002/bjs.7419>
6. Kelley SR, Duchalais E, Larson DW (2018) Robotic right colectomy with intracorporeal anastomosis for malignancy. *J Robot Surg*. <https://doi.org/10.1007/s11701-017-0759-0>
7. Larson DW, Lovely JK, Cima RR, et al (2014) Outcomes after implementation of a multimodal standard care pathway for laparoscopic colorectal surgery. *BJS* 101:1023–1030. <https://doi.org/10.1002/bjs.9534>
8. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 240:205–213. <https://doi.org/10.1097/01.sla.0000133083.54934.ae>
9. Bhem KT, Larson DW (2019) Robotic surgery: clinical perceptions. Approaches and Challenges. nova science publishers, Washington, DC
10. Feroci F, Lenzi E, Garzi A et al (2013) Intracorporeal versus extracorporeal anastomosis after laparoscopic right hemicolectomy for cancer: a systematic review and meta-analysis. *Int J Colorectal Dis*. <https://doi.org/10.1007/s00384-013-1651-7>
11. Emile SH, Elfeki H, Shalaby M et al (2019) Intracorporeal versus extracorporeal anastomosis in minimally invasive right colectomy: an updated systematic review and meta-analysis. *Tech Coloproctol*. <https://doi.org/10.1007/s10151-019-02079-7>
12. Genova P, Pantuso G, Cipolla C et al (2020) Laparoscopic versus robotic right colectomy with extra-corporeal or intra-corporeal anastomosis: a systematic review and meta-analysis. *Langenbeck's Arch Surg*. <https://doi.org/10.1007/s00423-020-01985-x>
13. Bollo J, Turrado V, Rabal A et al (2020) Randomized clinical trial of intracorporeal versus extracorporeal anastomosis in laparoscopic right colectomy (IEA trial). *Br J Surg*. <https://doi.org/10.1002/bjs.11389>
14. Grams J, Tong W, Greenstein AJ, Salky B (2010) Comparison of intracorporeal versus extracorporeal anastomosis in laparoscopic-assisted hemicolectomy. *Surg Endosc* 24:1886–1891. <https://doi.org/10.1007/s00464-009-0865-9>
15. Kim JY, Kim NK, Lee KY et al (2012) A comparative study of voiding and sexual function after total mesorectal excision with autonomic nerve preservation for rectal cancer: Laparoscopic versus robotic surgery. *Ann Surg Oncol*. <https://doi.org/10.1245/s10434-012-2262-1>
16. Allaix ME, Degiuli M, Bonino MA et al (2019) Intracorporeal or extracorporeal ileocolic anastomosis after laparoscopic right colectomy: a double-blinded randomized controlled trial. *Ann Surg*. <https://doi.org/10.1097/SLA.0000000000003519>

17. Scatizzi M, Kröning KC, Borrelli A et al (2010) Extracorporeal versus intracorporeal anastomosis after laparoscopic right colectomy for cancer: a case-control study. *World J Surg.* <https://doi.org/10.1007/s00268-010-0743-6>
18. Iorio T, Blumberg D (2014) A case-control study examining the benefits of laparoscopic colectomy using a totally intracorporeal technique for left-sided colon tumors. *Surg Laparosc Endosc Percutaneous Tech.* <https://doi.org/10.1097/SLE.0b013e318290155b>
19. Bucher P, Wutrich P, Pugin F et al (2008) Totally intracorporeal laparoscopic colorectal anastomosis using circular stapler. *Surg Endosc Other Interv Tech* 22:1278–1282. <https://doi.org/10.1007/s00464-007-9607-z>
20. Nishimura A, Kawahara M, Suda K et al (2011) Totally laparoscopic sigmoid colectomy with transanal specimen extraction. *Surg Endosc.* <https://doi.org/10.1007/s00464-011-1716-z>
21. Di Saverio S, Birindelli A, Mandrioli M et al (2017) Intracorporeal anastomoses in emergency laparoscopic colorectal surgery from a series of 59 cases: where and how to do it—a technical note and video. *Color Dis.* <https://doi.org/10.1111/codi.13642>
22. Di Saverio S, Birindelli A, Segalini E et al (2018) “To stent or not to stent?”: immediate emergency surgery with laparoscopic radical colectomy with CME and primary anastomosis is feasible for obstructing left colon carcinoma. *Surg Endosc.* <https://doi.org/10.1007/s00464-017-5763-y>
23. Di Saverio S, Vennix S, Birindelli A et al (2016) Pushing the envelope: laparoscopy and primary anastomosis are technically feasible in stable patients with Hinchey IV perforated acute diverticulitis and gross faeculent peritonitis. *Surg Endosc.* <https://doi.org/10.1007/s00464-016-4869-y>
24. Jiang JK, Yang SH, Lin JK (2005) Transabdominal anastomosis after low anterior resection: a prospective, randomized, controlled trial comparing long-term results between side-to-end anastomosis and colonic J-pouch. *Dis Colon Rectum.* <https://doi.org/10.1007/s10350-005-0139-0>
25. Mäkelä JT, Kiviniemi H, Laitinen S (2003) Risk factors for anastomotic leakage after left-sided colorectal resection with rectal anastomosis. *Dis Colon Rectum* 46:653–660. <https://doi.org/10.1007/s10350-004-6627-9>
26. Brisinda G, Vanella S, Cadeddu F et al (2009) End-to-end versus end-to-side stapled anastomoses after anterior resection for rectal cancer. *J Surg Oncol.* <https://doi.org/10.1002/jso.21182>
27. Rybakov EG, Pikunov DY, Fomenko OY, et al (2016) Side-to-end vs. straight stapled colorectal anastomosis after low anterior resection: results of randomized clinical trial. *Int J Colorectal Dis.* <https://doi.org/10.1007/s00384-016-2608-4>

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