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Comparing extracorporeal, semi-extracorporeal, and intracorporeal anastomosis in laparoscopic right hemicolectomy: introducing a bridging technique for colorectal surgeons

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Purpose: Intracorporeal anastomosis (IA) in laparoscopic right hemicolectomy has been associated with faster recovery in bowel function compared to extracorporeal anastomosis (EA). However, the technical difficulty of laparoscopic suturing technique and intraabdominal fecal contamination hinder many surgeons from implementing such a procedure. We introduce and compare a bridging technique designated as "semi-extracorporeal" anastomosis (SEA), which embraces the advantages and amends the drawbacks of IA and EA.
Methods: Between May 2016 and October 2022, 100 patients who underwent laparoscopic right hemicolectomy were analyzed. All patients who received laparoscopic right hemicolectomy underwent one of the 3 anastomosis methods (EA, SEA, and IA) by a single colorectal surgeon at a single tertiary care hospital. Data including perioperative parameters and postoperative outcomes were analyzed by each group.
Results: A total of 100 patients were reviewed. Thirty patients underwent EA; 50 and 20 patients underwent SEA and IA, respectively. Operation time (minute) was 170 (range, 100–285), 170 (range, 110–280), and 147.5 (range, 80–235) in EA, SEA, and IA, respectively (P = 0.010). Wound size was smaller in SEA and IA compared to EA (P < 0.001). IA was associated with a shorter time (day) to first flatus compared to SEA and EA (4 [range, 2–13] *vs.* 4 [range, 2–7] *vs.* 2.5 [range, 1–4], P < 0.001). Postoperative complication showed no statistical significance between the 3 groups.
Conclusion: Semi-extracorporeal was an attractive bridging option for colorectal surgeons worrisome of the technical difficulty of IA while maintaining faster bowel recovery and smaller wound incisions compared to EA.
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Key Words: Surgical anastomosis, Laparoscopy, Hemicolectomy

INTRODUCTION

Laparoscopic right hemicolectomy is now the golden standard for benign or malignant disease of the right side of the colon since its first introduction in 1991 [1]. Bowel continuity was achieved through hand-sewn extracorporeal anastomosis (EA) until mechanical stapling devices came to light. As laparoscopic devices and equipment have advanced, so did the yearning for

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minimally invasive techniques. Intracorporeal anastomosis (IA) first mentioned as early as 1992 was generalized by a French surgeon in 2005 [2]. However, the technical difficulty of IA requiring advanced laparoscopic suturing techniques has hindered many colorectal surgeons from quickly adapting this method of anastomosis [3]. Meta-analyses and randomized controlled trials (RCTs) comparing ECA and IA favor IA in terms of early recovery of bowel function and hospital stay, but conflicting results of infection and anastomosis leakage have been reported [4-7]. Semi-EA (SEA) is a combination of EA and IA in which the bowels are transected intracorporeally with anastomosis performed extracorporeally ameliorating the drawbacks and maintaining the advantages of the 2 techniques. We believe SEA may be a suitable bridging option for intermediate colorectal surgeons as well as general surgeons performing laparoscopic right hemicolectomies.

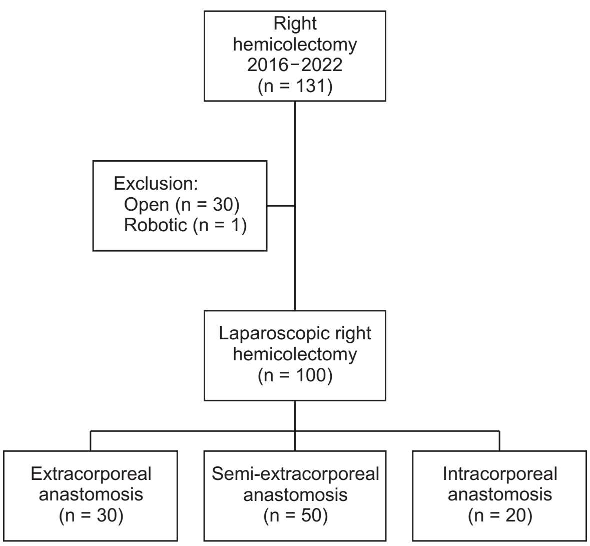

Fig. 1. Flowchart of selection of patients.

METHODS

Ethics statement

This study was approved by the Institutional Review Board and Ethics Committees of CHA Bundang Medical Center (No. 2022-11-005) and was conducted according to the principles of the Declaration of Helsinki. A written informed consent was not required for this retrospective study.

Subjects

Between May 2016 and October 2022, 131 patients underwent right hemicolectomy by a single surgeon. Laparoscopic right hemicolectomy was performed in 100 patients, robotics surgery in 1 patient, and open colectomy in 30 patients. All patients who received laparoscopic right hemicolectomy underwent one of the 3 anastomosis methods (EA, SEA, and IA) by a single colorectal surgeon (Fig. 1). The type of anastomosis chosen and performed depended on the timing of the operation. Most of the patients who underwent laparoscopic right hemicolectomy during the early days (2016–2018) were in the extracorporeal group, and the recent 20 patients underwent IA. Patients during the bridging period between 2018 and 2021 underwent SEA. Prospectively collected data were retrospectively reviewed. Demographics, such as age, sex, body mass index (BMI), American Society of Anesthesiology physical status (ASA PS) classification, and diagnosis of the patient were collected. Perioperative data included the emergent nature of the surgery, total operation time, blood loss, wound size, and intraoperative transfusion. Postoperatively, data including bowel motility, days of intravenous (IV) pain medication, length of hospital stay, complications, and readmission within 30 days were collected.

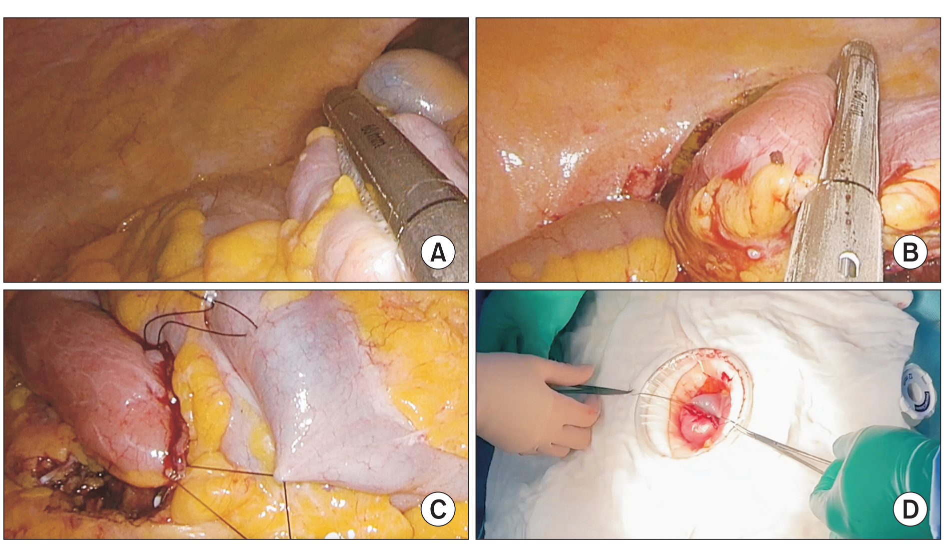

Fig. 2. Semi-extracorporeal anastomosis surgical technique. (A) Transverse colon resection with Endo GIA (Medtronic). (B) Terminal ileum resection with Endo GIA. (C) Intracorporeal tagging suture of the transected bowels. (D) Extracorporeal anastomosis performed in semi-extracorporeal anastomosis.

Surgical technique

All patients underwent laparoscopic right hemicolectomy. A transumbilical incision was made for a 12-mm camera port through which the pneumoperitoneum was made. Two main trocars for the operator were inserted at the left lower quadrant (12 mm) and at the suprapubic area (5 mm). One or two 5-mm assist ports were placed at the right upper quadrant and/or the right lower quadrant for traction. The method of dissection depended on the tumor status of the patient. For advanced cases with lateral wall invasion, a medial-to-lateral approach was performed while for those with thickened mesentery fat hindering appropriate traction and identifying proper plane, a lateral-to-medial approach was preferred. Full mobilization of the ascending and transverse colon up to the distal resection margin and mesenteric dissection of terminal ileum up to the proximal resection margin was performed. At this time, depending on the type of anastomosis chosen for the patient, the operation was continued accordingly.

An extension of the transumbilical incision was made for patients undergoing EA. The entire mobilized colon and terminal ileum including the mesentery was exteriorized. Bowels were transected, and hand-sewn or stapled anastomosis with EEA #25 (Medtronic) and Endo GIA (Signia, Medtronic) was carried out. Intracorporeally, bowels were resected with Endo GIA, and anastomosis was performed in isoperistaltic, side-to-side stapling method with closure of common channel via Monofix 3-0 barbed suture (Samyang Biopharm).

SEA is a method in which ileum and transverse colon are transected intracorporeally with Endo GIA (Fig. 2A, B). The lateral ends of the transected bowel are sutured laparoscopically with 3-0 silk to prevent mesentery rotation (Fig. 2C). Through the extended transumbilical incision, the tagged suture is pulled out after which end-to-side, hand-sewn bowel anastomosis is performed extracorporeally (Fig. 2D).

Statistical analysis

All analyses were performed using SAS ver. 9.4 (SAS Institute). Data including perioperative parameters and postoperative outcomes were analyzed by each group. The Shapiro-Wilk test was performed in all continuous variables. Normal distribution was not met; therefore, the Kruskal-Wallis test was used for the comparison of the 3 groups for which the median and range were expressed. Categorical variables were analyzed using the Pearson chi-square test or Fisher exact test. For the *post hoc* analysis P-values, Bonferroni correction was applied. For all variables, a P-value of <0.05 was considered statistically significant.

RESULTS

Baseline characteristics for patients who underwent EA, SEA, and IA are shown in Table 1. Age, Sex, BMI, and ASA PS classification were comparable between all 3 groups. The most common cause of operation was ascending colon cancer in all 3 groups: 23 patients in EA, 41 patients in SEA, and 13 patients in IA. Emergency cases were also included in all 3 groups with no statistical significance. Data on lesion complications, such as perforation, intussusception, obstruction, and bleeding were collected with 7 patients in EA, 15 patients in SEA, and 5 patients in IA.

Median operative time was 170 minutes (range, 100–285 minutes) in the EA group, 170 minutes (range, 110–280 minutes) in the SEA group, and 147.5 minutes (range, 80–235 minutes) in the IA group with a statistical significance (P = 0.010). In *post hoc* analysis, the IA group showed a significantly shorter operation time compared to the SEA group (P = 0.009). Estimated blood loss was statistically higher in the IA group compared to the EA group (80 mL *vs.* 50 mL, P = 0.022) but no significance was found in intraoperative transfusion (P = 0.442). Although the SEA group seemed to have the largest tumor size patients (mean [range]: EA, 3.3 cm [0–13 cm] *vs.* SEA, 5.25 cm [0.2–13.5 cm] *vs.* IA, 3.25 cm [0–13 cm]), no statistically significant difference was seen in either analysis of variance (P = 0.058) or *post hoc* analysis. Favorable results were shown for the SEA and IA groups regarding wound size compared to the EA group (P < 0.001). The median wound size for the EA group was 6 cm (range, 4–8 cm), 4 cm (range, 4–7 cm) for the SEA group, and 4 cm (range, 3.5–5.5 cm) for the IA group. Although SEA and IA both showed significantly reduced wound size compared to EA (both P < 0.001), there was no significant difference between SEA and IA. Time to first flatus recorded in number of days was also statistically significant: 4 days (range, 2–13 days) for EA, 4 days (range, 2–7 days) for SEA, and 2.5 days (range, 1–4 days) for IA (P < 0.001). In a separate analysis comparing SEA and IA, the IA group showed a shorter time to first flatus with statistical significance (P = 0.001). However, these results did not lead to a shorter time to the first stool. Length of IV pain medication, defined as the length of IV opioid required, was also favorable towards the SEA and IA groups (5.5 days *vs.* 3 days *vs.* 3 days, P < 0.001). All patients received a continuous infusion of IV patient-controlled analgesia for 2–3 days and were discharged with oral NSAIDs for at-home pain control. Similar *post hoc* analysis findings were seen in the length of IV pain medication as in wound size. The length of hospital stay was 8 days (range, 6–32 days) in the EA group, 7 days (range, 5–27 days) in the SEA group, and 7 days (range, 5–13 days) in the IA group with statistical significance (P = 0.029). Patients were discharged significantly earlier in the IA group than in the EA group (P = 0.043). The intraoperative and postoperative outcomes are shown in Table 2.

Postoperative complication showed no statistical significance between the 3 groups, yet the IA group showed an upward

Table 1. Baseline characteristics

Variable	EA group	SEA group	IA group	Overall P-value	*Post hoc* analysis P-value (Bonferroni)		
					EA *vs.* SEA	EA *vs.* IA	SEA *vs.* IA
No. of patients	30	50	20				
Age (yr)	73.5 (56–91)	69 (43–90)	63 (35–86)	0.180			
Sex				0.410			
Male	12 (40.0)	19 (38.00)	11 (55.0)				
Female	18 (60.0)	31 (62.00)	9 (45.0)				
Body mass index (kg/m^2)	22.99 (16.80–31.15)	23.83 (17.75–31.52)	23.12 (18.61–32.82)	0.480			
ASA PS classification				0.130			
I	4 (13.3)	2 (4.0)	1 (5.0)				
II	17 (56.7)	34 (68.0)	14 (70.0)				
III	9 (30.0)	14 (28.0)	3 (15.0)				
IV	0 (0)	0 (0)	2 (10.0)				
Cause of operation				0.005*	>0.999	0.049*	0.011*
Appendiceal cancer	1 (3.3)	3 (6.0)	0 (0)				
Ascending colon cancer	23 (76.7)	41 (82.0)	13 (65.0)				
Transverse colon cancer	6 (20.0)	6 (12.0)	2 (10.0)				
Benign/Others	0 (0)	0 (0)	5 (25.0)				
Emergency				0.370			
Yes	5 (16.7)	8 (16.0)	6 (30.0)				
No	25 (83.3)	42 (84.0)	14 (70.0)				
Lesion complication				0.790			
0	23 (76.7)	35 (70.0)	15 (75.0)				
1	7 (23.3)	15 (30.0)	5 (25.0)				

Values are presented as number (%) or median (range).
EA, extracorporeal anastomosis; SEA, semi-extracorporeal anastomosis; IA, intracorporeal anastomosis; ASA, American society of Anesthesiologists; PS, physical status.
*$P < 0.05$.

Table 2. Intraoperative and postoperative outcomes

Variable	EA group (n = 30)	SEA group (n = 50)	IA group (n = 20)	Overall P-value	*Post hoc* analysis P-value (Bonferroni)		
					EA *vs.* SEA	EA *vs.* IA	SEA *vs.* IA
Operative time (min)	170.0 (100–285)	170.0 (110–280)	147.5 (80–235)	0.010*	>0.999	0.087	0.009*
Estimated blood loss (mL)	50 (0–500)	75 (0–1,500)	80 (0–470)	0.022*	0.058	0.032	>0.999
Intraoperative transfusion				0.442			
Yes	1 (3.33)	6 (12.00)	1 (5.00)				
No	29 (96.67)	44 (88.00)	19 (95.00)				
Tumor size (cm)	3.3 (0–13)	5.25 (0.2–13.5)	3.25 (0–13)	0.058	0.230	>0.999	0.110
Wound size (cm)	6 (4–8)	4 (4–7)	4 (3.5–5.5)	<0.001*	<0.001*	<0.001*	>0.999
Time to first flatus (day)	4 (2–13)	4 (2–7)	2.5 (1–4)	<0.001*	0.538	<0.001*	0.001*
Time to first stool (day)	4 (2–13)	4 (2–10)	3.5 (2–6)	0.070			
Time to first meal (day)	2 (2–12)	2 (2–16)	2 (2–4)	0.140			
Length of IV pain medication (day)	5.5 (3–10)	3 (2–12)	3 (1–4)	<0.001*	0.001*	<0.001*	0.405
Length of hospital stay (day)	8 (6–32)	7 (5–27)	7 (5–13)	0.029*	0.156	0.043*	0.768

Values are presented as number (%) or median (range).
EA, extracorporeal anastomosis; SEA, semi-extracorporeal anastomosis; IA, intracorporeal anastomosis.
*P < 0.05.

Table 3. Postoperative complications

Variable	EA group (n = 30)	SEA group (n = 50)	IA group (n = 20)
Postoperative complications			
No	25 (83.4)	46 (92.0)	15 (75.0)
Yes	5 (16.6)	4 (8.0)	5 (25.0)
Grade I			
Seroma	1	0	0
Surgical site infection	1	0	2
Ileus	1	0	1
Ascites	0	1	0
Pseudomembranous colitis	0	0	2
Grade II, ileus	1	2	0
Grade III, wound dehiscence	1	0	0
Grade IV	1	0	0
Grade V	0	2	0
Readmission within 3 mo			
Yes	1 (3.3)	0 (0)	1 (5.0)
No	29 (96.7)	50 (100)	19 (95.0)

Values are presented as number (%) or number only.

trend of surgical site infection shown in Table 3. There were 2 cases of mortality in the SEA group due to the patients' underlying disease, and 1 case of readmission within 3 months in the IA and EA groups, respectively.

DISCUSSION

The first right hemicolectomy mentioned in the literature was performed by Lowson [8] in 1893. In his 2-page commentary on the account of a case of malignant disease of the ascending colon, he described his surgical procedure in detail of what we now know as an open right hemicolectomy. The first laparoscopic right hemicolectomy was performed in 1991 [1]. However, unique characteristics specific to right hemicolectomy, such as anatomic variation of vasculature and various approaches to lymph node dissection and anastomosis hindered early adaptation of laparoscopy [9]. Many RCTs have proven the benefit and oncologic safety of laparoscopic surgery [10-12]. Even when focused on right hemicolectomies, the benefits of laparoscopy compared to open procedure have been accepted [13-15]. Recently, colorectal surgeons around the world have taken a step further in this minimally invasive era campaigning for laparoscopic anastomosis otherwise known as "intracorporeal anastomosis."

In Lowson's account of his first right hemicolectomy, a hand-sewn, side-to-side isoperistaltic anastomosis was made using Senn's bone plates [8]. In Corman's text [16], end-to-end, single-layer, interrupted anastomosis is introduced. Over the years, different anastomosis techniques have been established with the introduction of stapled devices. The first mechanical stapling device mentioned was by Ravitch et al. [17] in 1959.

Modifications have been made over the years and marketed for gastrointestinal surgeries in 1967.

One of the most dreadful complications colorectal surgeons face is anastomosis leakage reported at a range between 0.5% and 7.0% [18-20]. Numerous meta-analyses of RCTs have been published since the 1990s comparing hand-sewn and stapled anastomosis in colorectal surgeries concluding no significant difference in anastomosis leakage between the 2 techniques [21,22]. A meta-analysis conducted by Choy et al. [23] known as the largest systematic review focusing specifically on ileocolic anastomosis concluded the superiority of stapled anastomosis in anastomosis leakage (2.5% *vs.* 6%). At a clinical level, however, the 2 methods were comparable at 2.3% and 4.2% with no statistical significance. Currently, there is a concrete consensus that hand-sewn and stapled anastomoses are comparable in anastomosis leakage, and the method of choice chosen should reside in the preference of the surgeon.

As evidence of superior postoperative patient recovery has been reported regarding IA, studies comparing IA and EA have emerged [24]. By exteriorizing the bowel, the surgeon can manually palpate the location of the diseased bowel procuring adequate resection margins. Moreover, spillage of the bowel content can be avoided. When performing IA, all procedures are performed intracorporeally allowing minimal dissection of mesentery and omentum. Minimal wound extension for specimen retrieval is needed, which explains the statistical significance of wound size between each group. For SEA and IA procedures, wound size depended on the size of the specimen while the EA group required sufficient space for exteriorization. Even with an average incision size of 4 cm in SEA, end-to-side hand-sewn anastomosis can be performed without much difficulty since the anastomosis size depends on the lumen size of the small bowel. Functional end-to-end stapled anastomosis is also a viable option for those not quite familiar with hand-sewn anastomosis.

Of the 3 RCTs currently published comparing EA and IA, Allaix et al. [4] and Bollo et al. [5] collected data on postoperative pain and analgesic requirements. Both RCTs showed a decreased level of postoperative pain using the visual analog scale score in the IA group with statistical significance with lower weighted postoperative analgesia requirement. In our study, we initially collected data regarding pain scores on postoperative days 1, 3, and 5. However, we believed that quantifying pain was subjective and depended on the characteristics of the patient and not the type of anastomosis used. Therefore, we collected data on the length of IV analgesic required, and with statistical significance, the IA and SEA group at its shortest and EA at its longest (5.5 days *vs.* 3 days *vs.* 3 days, $P < 0.001$). One can deduce that the requirement for analgesics has a direct relationship with wound size: the smaller the size of the wound, the shorter the duration of analgesia.

The 2 techniques are not without flaws. Increased mesenteric traction results in unwanted mesenteric bleeding and serosal tearing leading to the longer recovery of bowel function. Exteriorizing both the bowels and the mesentery requires more extension of the wound resulting in higher rates of incisional hernia in EA. On the other hand, early malignancies and post-endoscopic submucosal dissection lesions requiring surgery are almost impossible to locate intracorporeally. The exposure of peritoneum to potential intraluminal contamination is a worrisome complication discussed in many studies comparing EA and IA [6]. Most of all, the technical difficulty of laparoscopic suturing is an obstacle for many fledgling colorectal surgeons.

We report postoperative complications according to the Clavien-Dindo classification. A total number of 15 postoperative complications were reported with 5 patients uniformly in each group ($P = 0.158$). Twelve patients were at grade 2 or less mostly due to infection and ileus, and only 3 patients were reported to be grade 3 or higher. Although statistically not significant, the IA group showed a trend of surgical site infection. There were 2 cases of mortality in the SEA group due to the patients' underlying disease. One patient suffered from hepatic failure due to innumerable hepatic metastases apparent from the initial diagnosis of obstructive ascending colon cancer. The other mortality was a result of aspiration pneumonia secondary to underlying Parkinson disease.

Many studies have reported higher rates of incisional hernia in the EA group [25,26]. According to Feo et al. [25], all EA specimens were extracted through the extension of the umbilicus wound, while the IA specimen extraction site varied from umbilicus, right lower quadrant trocar site, or Pfannenstiel incision. Hellan et al. [26] reported the incidence of incisional hernia in IA only in patients whose specimen was not removed through a Pfannenstiel incision. However, the most recent meta-analysis by Frigault et al. [27] reported no difference in the incidence of incisional hernia by incision site ($P = 0.19$). All the specimens in our study were extracted through the extension of the transumbilical wound regardless of the type of anastomosis performed. Additional incision at the suprapubic site for extraction seemed unnecessary, and with technically robust fascia closure and use of barbed suture material, we can prevent the occurrence of incisional hernia [28]. At a median follow-up of 24 months, we currently report no cases of incisional hernia in any of the groups.

There are studies where the operation time between the 2 groups did not incur statistical significance [4,26]. However, in the most recent meta-analysis of 6,570 patients by Lam et al. [29], the operation time was longer in IA group ($P < 0.01$; weighted mean difference, 13.32 minutes; 95% confidence interval, 6.57–20.06; I_2, 92%) mainly due to the difficulty of laparoscopic suturing technique. Interestingly, median operation time in our study were 170, 170, and 147 minutes in the EA, SEA, and

IA groups, respectively with statistical significance (P = 0.010). There are 2 reasons behind such a result. First, the majority of EA and SEA (83.8%) were performed via hand-sewn anastomosis while all IA was performed with Endo GIA and continuous laparoscopic suture. Hand-sewn anastomosis of double-layer technique resulted in longer operation time than anastomosis by stapler. Also, the expert laparoscopic suturing skill of the surgeon also contributed to the shorter operation time.

The most updated systemic analysis of 47 studies comprising 3 RCTs, 3 case-controlled studies, and 41 retrospective cohort studies reported that IA was associated with shorter time to oral feeding, first bowel movement, and first flatus (all P < 0.01) [29]. Likewise, the time to the first flatus was shortest in the IA group with significance in our study (P < 0.001). Even in a subgroup analysis of SEA and IA, the time to first flatus was 4 days and 2.5 days, respectively (P < 0.001). Time to first stool, on the other hand, was 4 days and 3.5 days, respectively, but was not statistically significant (P = 0.072).

The length of hospital stay in our study was 8 days, 7 days, and 7 days in the EA, SEA, and IA groups, respectively, with statistical significance (P = 0.030). Faster recovery in bowel function led to faster discharge. However, the 3 RCTs reported no statistical significance in the duration of admission [4,5]. Many factors determine the length of hospital stay, and one of the variables is recovery of bowel function. However, other multifactorial variables, especially postoperative complications, may lengthen a patient's hospital stay regardless of swift recovery in bowel function, which may explain the results of the RCTs.

Our study is different from other studies comparing EA and IA. The 2 different anastomosis techniques were not performed during the same time period, but rather years apart. This study was designed to share the experience of a single colorectal surgeon from his novice years to his expert era, gradually adopting challenging techniques over time. Given the pros and cons of EA and IA, we aim to introduce a suitable bridging technique of SEA that bears the advantage of both techniques while compensating for the drawbacks. Moreover, the inclusion of benign diseases, such as diverticulitis and Crohn disease may have affected the results of our study. Nonetheless, we were able to show non-inferiority of SEA compared to IA in terms of early recovery to bowel function and wound size.

Laparoscopic right hemicolectomy is routinely performed for diseases of the ascending colon. EA and IA are options for constructing bowel continuity with pros and cons well-established by numerous analyses. SEA may be a suitable bridging technique for colorectal and general surgeons hoping to embrace the benefits of early recovery in bowel function, smaller wound size, and shorter operation time concerned about the technical difficulty of laparoscopic suturing skill and intraabdominal and surgical site infection.

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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