Introduction

Laparoscopic techniques were adopted by general surgeons in the 1980s with subsequent adaptation to colorectal surgery in 1991 (1). The robotic approach was introduced to colorectal surgery in 2002 (2,3) and upgrades in the robotic platform have resulted in recent increased adoption by colorectal surgeons. Subsequent studies demonstrated improved minimally invasive short-term post-operative outcomes, with earlier return of bowel function, lower analgesia requirements, and shorter hospital length of stay (4,5). Data have also demonstrated equivalent oncologic outcomes for patients undergoing minimally invasive colon resections when compared to open operations, with associated decreased post-operative morbidity (6,7). Recent data suggest a continued increase in the use of minimally invasive approaches for both benign and malignant colorectal disease (8).

How to restore intestinal continuity and create a superior anastomosis is still a topic for consideration in colorectal surgery. Minimizing infectious complications that include anastomotic leak, post-operative abscess, and surgical site infection is imperative, but decreasing time to discharge and quicker recovery are also key outcomes. Minimally invasive ileocolic and colorectal anastomoses may be performed using intracorporeal (or total laparoscopic/robotic) or extracorporeal (or laparoscopic/robot assisted) techniques. This article is a review of operative techniques for both intracorporeal anastomosis (IA) and extracorporeal anastomosis (EA), and an examination of published data comparing each approach.
Descriptions and critiques of anastomotic techniques

 Extracorporeal anastomosis

Anastomotic technique

For right colectomies, after complete mobilization of the terminal ileum, cecum, ascending colon, and proximal transverse colon, an upper midline incision is typically made by extending the camera port incision along the midline. The mobilized ileum and colon are then exteriorized after insertion of a wound protector. The terminal ileum and transverse colon are divided and the ileocolic anastomosis is constructed using standard open techniques. Some surgeons divide the mesentery and vessels laparoscopically or robotically prior to exteriorizing the specimen and performing the extracorporeal resection and anastomosis. Others perform various parts of mesenteric and vessel division after exteriorization of the specimen and prior to bowel division and anastomosis.

After division of the specimen, an extracorporeal functional end-to-end anastomosis is then constructed by aligning the ileum and transverse colon in an isoperistaltic or antiperistaltic fashion. Enterotomies are made in the ileum and transverse colon and a linear cutter 55 or 75 mm blue load stapler is placed through these enterotomies and fired, thereby creating the anastomosis. The common enterotomy is then sutured closed in one or two layers.

For left colectomies, after adequate mobilization, the upper rectum is transected using a laparoscopic or robotic linear stapler. A midline or Pfannenstiel incision is made, a wound protector is placed, and the proximal end of the transected bowel is delivered through the incision thereby exteriorizing the specimen still attached to the proximal colon. The specimen is resected using standard open techniques. A circular stapler anvil is secured in the open proximal end of soft and pliable colon using a purse string suture. The colon with secured anvil is returned to the abdominal cavity and pneumoperitoneum reinstituted. The circular stapler is passed through the anus and coupled with the anvil in the proximal colon, and an end-to-end anastomosis is created either laparoscopically or with robotic assistance. The anastomosis is tested for leaks using endoscopic air insufflation with saline in the pelvis, and endoscopic viability is confirmed on both sides of the anastomosis.

Extracorporeal anastomosis advantages

Exteriorization of the proximal and distal bowel with attached specimen allows for visual inspection and palpation prior to resection and anastomosis. Some surgeons think this may help confirm healthy, soft and viable bowel for anastomosis and confirm appropriate margins for oncologic resections. Since bowel transection and creation of the anastomosis occur outside of the abdominal cavity, there is potentially a decrease in risk of intra-abdominal spillage of colonic contents related to this technique.

Extracorporeal anastomosis disadvantages

Because of the need to exteriorize the bowel for resection and anastomosis, significantly more bowel and mesentery must be mobilized to obtain adequate reach for specimen resection and anastomosis, especially in obese patients with thick abdominal walls. For right hemicolectomies, exteriorizing the transverse colon to a small midline specimen extraction site may be challenging with risk of traction injury to bowel or mesentery. This may result in serosal injuries, mesenteric bleeding, and devascularization of bowel and mesentery that may potentially contribute to post-operative ileus (9). The transverse colon may not reach the extraction site easily and the midline incision may need to be lengthened to accommodate. Many surgeons use a midline extraction site for extracorporeal right colectomies. The midline site is associated with a significantly higher rate of incisional hernias (8–12%) with associated long-term morbidity when compared to off-midline extraction sites (10,11).

Intracorporeal anastomosis

Anastomotic technique

For right colectomies, an intracorporeal ileo-transverse colon anastomosis is typically chosen for the minimally invasive approach (see Figure 1). Following complete medial-to-lateral and lateral-to-medial mobilization of the ileum and colon, and complete detachment of the mesentery from the retroperitoneum, the terminal ileum and transverse colon are transected using a laparoscopic or robotic linear cutter stapler. The ileum and transverse colon are aligned in either an isoperistaltic or antiperistaltic configuration. A seromuscular stay suture is placed between the ileum and transverse colon, and complete detachment of the mesentery to the retroperitoneum, the terminal ileum and transverse colon are transected using a laparoscopic or robotic linear cutter stapler. The ileum and transverse colon are aligned in either an isoperistaltic or antiperistaltic configuration. A seromuscular stay suture is placed between the ileum and transverse colon and retracted toward the right side of the abdomen to optimize alignment. A colotomy and enterotomy are then made and the linear cutter stapler is placed and fired, creating the anastomosis. The common enterotomy is then closed with suture in one or two layers. The specimen is then removed via a small Pfannenstiel or other off-midline incision.

When describing anastomotic options for left colectomies, it may be best to refer to intracorporeal
technique rather than intracorporeal anastomosis (12). The anastomosis is “intracorporeal” for both intracorporeal and extracorporeal techniques. However, the entire operation prior to specimen extraction that includes mobilization of the mesentery and division of the vessels, upper rectum, and proximal colon, followed by placement of the anvil and creation of the anastomosis, are all done within the abdomen for the intracorporeal technique (see Figure 2).

In contrast, the extracorporeal left colectomy technique is characterized by resection of the specimen and placement of the anvil after delivering the specimen through the extraction site incision using standard open techniques.

The intracorporeal technique starts with medial-to-lateral mobilization of the descending and sigmoid colon and mesentery. The inferior mesenteric vessels are divided after identification of the left ureter. Lateral-to-medial mobilization of the left colon is followed by intracorporeal division of the upper rectum using a laparoscopic or robotic linear cutter stapler. The mesentery is divided from point of transection of the inferior mesenteric artery to the proposed point of transection of the descending colon. A long 3–4 cm colotomy is made distal, and a small 6 mm colotomy made proximal to the proposed point of transection of the descending colon. The anvil is introduced into the abdomen through either a Pfannenstiel or other off-midline extraction site incision. After re-establishing pneumoperitoneum, the anvil is passed through the long colotomy and then the shaft of the anvil routed through the small colotomy proximal to the proposed point of transection. The descending colon is then divided with a linear cutter stapler after confirming viability with immunofluorescence. The long colotomy, now on the specimen side, is closed with a running suture and the specimen is set aside until completion of the anastomosis. The circular stapler is passed through the anus and coupled with the anvil on the descending colon and a side-of-colon to end-of-rectum anastomosis is created. The specimen is then removed through a Pfannenstiel or other off-midline extraction site incision.

Intracorporeal anastomosis advantages
Since the colon does not require exteriorization for resection and anastomosis, there is no need to mobilize bowel that will remain in-situ, and no traction is required to deliver the specimen to a small extraction site incision. This decreases the risk for mesenteric bleeding, serosal injuries, and the occasional need to extend the extraction site incision. This may result in less ileus (9). The length of the IA extraction site incision is not influenced by whether
the colon will reach, and the size of the IA extraction site incision is limited only by the size of the specimen (12). For some morbidly obese patients, the only minimally invasive option may be an IA approach because of the degree of difficulty related to thick and short mesentery reaching an extracorporeal extraction site in a thick abdominal wall (9,12). Because the specimen may be removed at any off-midline location, the risk for incisional hernia and subsequent related long-term morbidity from complex hernia mesh repair is reduced (10,11).

**Review of published data**

**Right colectomies**

*Table 1* displays single and multi-institution studies that compare outcomes for minimally invasive IA and EA right colectomies. Many studies show favorable outcomes for IA, demonstrating decreased conversion-to-open operations, shorter gastrointestinal recovery time, shorter hospital length of stay, and decreased postoperative complications, including both short-term (surgical site infection, anastomotic leak, and ileus) and long term (incisional hernia and small bowel obstruction) complications (9,13,15-18) when compared to EA. Operative times in the IA group were longer than in the EA group in most of these studies (9,15,17).

A propensity-matched comparison of 379 IA right colectomies (335 robotic-assisted and 44 laparoscopic) and 650 EA right colectomies (253 robotic-assisted and 397 laparoscopic) showed significantly lower conversion rates (0.3% vs. 2.9%, P=0.01), shorter hospital length of stay (4.0 vs. 4.5 days, P=0.02) and fewer 30-day postoperative
Table 1 Outcomes comparison of intracorporeal (IA) and extracorporeal (EA) right hemicolectomies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>MIS type</th>
<th>Operative time (min)</th>
<th>Conversion to open (%)</th>
<th>All complications (%)</th>
<th>SSI (%), IA vs. EA (P)</th>
<th>AL (%), IA vs. EA (P)</th>
<th>Ileus (%), IA vs. EA (P)</th>
<th>IH (%), IA vs. EA (P)</th>
<th>SBO (%), IA vs. EA (P)</th>
<th>LOS (days), IA vs. EA (P)</th>
<th>Study design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feroci et al.</td>
<td>2013</td>
<td>Lap</td>
<td>425</td>
<td>N/A</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
<td>No difference</td>
<td>N/A</td>
<td>N/A</td>
<td>Shorter in IA (&lt;0.01)</td>
<td>Systematic review and meta-analysis</td>
</tr>
<tr>
<td>Hanna et al.</td>
<td>2015</td>
<td>Lap</td>
<td>195 [44]</td>
<td>0 vs. 9.2 (&lt;0.05)</td>
<td>53 vs. 38 (&lt;0.05)</td>
<td>10 vs. 5.5 (&lt;0.05)</td>
<td>1.2 vs. 4.6 (NS)</td>
<td>22 vs. 8 (&lt;0.05)</td>
<td>N/A</td>
<td>N/A</td>
<td>5.0 vs. 5.0 (NS)</td>
<td>Retrospective review</td>
</tr>
<tr>
<td>Shapiro et al.</td>
<td>2015</td>
<td>Lap</td>
<td>191 [48]</td>
<td>1.1 vs. 1.0 (&lt;0.01)</td>
<td>18.7 vs. 35 (0.01)</td>
<td>4.4 vs. 14 (0.02)</td>
<td>0 vs. 3 (0.25)</td>
<td>6.6 vs. 10 (NS)</td>
<td>2.2 vs. 17 (&lt;0.01)</td>
<td>0 vs. 2 (0.50)</td>
<td>5.9 vs. 6.9 (0.04)</td>
<td>Prospective comparative study</td>
</tr>
<tr>
<td>Biondi et al.</td>
<td>2017</td>
<td>Lap</td>
<td>116 [50]</td>
<td>N/A</td>
<td>16.7 vs. 16.7 [1]</td>
<td>3 vs. 6 (NS)</td>
<td>0 vs. 1 (NS)</td>
<td>1 vs. 0 (NS)</td>
<td>1.9 vs. 21.2 (&lt;0.01)</td>
<td>1.9 vs. 3.8 (0.54)</td>
<td>4.8 vs. 6.8 (&lt;0.01)</td>
<td>Retrospective review</td>
</tr>
<tr>
<td>Akram et al.</td>
<td>2018</td>
<td>Robot</td>
<td>110 [50]</td>
<td>0 vs. 12.7 (0.01)</td>
<td>0.78 vs. 1.91 (&lt;0.01)</td>
<td>0 vs. 7.3 (0.12)</td>
<td>0 vs. 9.1 (0.06)</td>
<td>9.1 vs. 21.8 (0.11)</td>
<td>0 vs. 9 (0.06)</td>
<td>N/A</td>
<td>3 vs. 3 (0.92)</td>
<td>Retrospective propensity-score comparison (single site)</td>
</tr>
<tr>
<td>Cleary et al.</td>
<td>2018</td>
<td>Lap &amp; Robot</td>
<td>1,029 [37]</td>
<td>0.3 vs. 2.9 (&lt;0.01)</td>
<td>5 vs. 8.9 (0.04)</td>
<td>0.5 vs. 1.4 (NS)</td>
<td>0.0 vs. 0.9 (NS)</td>
<td>2.4 vs. 2.9 (NS)</td>
<td>N/A</td>
<td>N/A</td>
<td>4 vs. 4.5 (0.02)</td>
<td>Retrospective propensity-score comparison (multiple site)</td>
</tr>
<tr>
<td>Ricci et al.</td>
<td>2016</td>
<td>Lap</td>
<td>1,717 [50.3]</td>
<td>129 vs. 121 (0.46)</td>
<td>2.8 vs. 4.7 (0.41)</td>
<td>27.6 vs. 38.4 (&lt;0.01)</td>
<td>4.9 vs. 8.9 (0.03)</td>
<td>3.4 vs. 4.6 (0.12)</td>
<td>N/A</td>
<td>2.3 vs. 13.7 (0.02)</td>
<td>5 vs. 5 (NS)</td>
<td>Systematic review and meta-analysis</td>
</tr>
<tr>
<td>van Oosten- dorp et al.</td>
<td>2016</td>
<td>Lap</td>
<td>1,492 [51]</td>
<td>N/A</td>
<td>Lower in IA (OR 0.68)</td>
<td>Lower in IA (OR 0.56)</td>
<td>No difference</td>
<td>No difference</td>
<td>N/A</td>
<td>N/A</td>
<td>Shorter by 0.7d in IA</td>
<td>Systematic review and meta-analysis</td>
</tr>
</tbody>
</table>

MIS, minimally invasive surgery; SSI, surgical site infection; AL, anastomotic leak; IH, incisional hernia; SBO, small bowel obstruction; LOS, length of stay; N/A, data not included/provided in study; NS, no significant difference reported by authors.
Table 2 Outcomes comparison of intracorporeal (IA) and extracorporeal (EA) left hemicolecotomies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>MIS type</th>
<th>N (%IA)</th>
<th>Operative time (min), IA vs. EA (P)</th>
<th>Conversion to Open (%), IA vs. EA (P)</th>
<th>All Complications (%), IA vs. EA (P)</th>
<th>AL (%), IA vs. EA (P)</th>
<th>ILIUS (%), IA vs. EA (P)</th>
<th>IH (%), IA vs. EA (P)</th>
<th>SBO (%), IA vs. EA (P)</th>
<th>LOS (days), IA vs. EA (P)</th>
<th>Study design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swaid et al. (21)</td>
<td>2015</td>
<td>Lap</td>
<td>52 [63]</td>
<td>132 vs. 124 (0.29)</td>
<td>0 vs. 0 (not given)</td>
<td>0 vs. 5 (0.37)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>4.2 vs. 6.3 (&lt;0.01)</td>
<td>Retrospective review</td>
</tr>
<tr>
<td>Al Natour et al. (12)</td>
<td>2018</td>
<td>Robot</td>
<td>114 [50]</td>
<td>193 vs. 160 (&lt;0.01)</td>
<td>5.26 vs. 19.3 (0.03)</td>
<td>0.579 vs. 1.75 (0.45)</td>
<td>N/A</td>
<td>0% vs. 10.5% (0.03)</td>
<td>N/A</td>
<td>2.9 vs. 4.0 (0.18)</td>
<td>Multi-Institution case control</td>
<td></td>
</tr>
<tr>
<td>Milone et al. (22)</td>
<td>2018</td>
<td>Lap</td>
<td>181 [51]</td>
<td>184 vs. 154 (&lt;0.01)</td>
<td>2 vs. 21 (&lt;0.01)</td>
<td>9.8 vs. 28.1 (0.01)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>6.1 vs. 6.8 (0.08)</td>
<td>Retrospective propensity-score comparison (single site)</td>
<td></td>
</tr>
<tr>
<td>Greico et al. (23)</td>
<td>2019</td>
<td>Lap</td>
<td>72 [50]</td>
<td>187 vs. 157 (0.07)</td>
<td>N/A</td>
<td>0 vs. 13.9 (0.04)</td>
<td>N/A</td>
<td>2.8 vs. 16.7 (0.05)</td>
<td>N/A</td>
<td>6 vs. 8.5 (&lt;0.01)</td>
<td>Retrospective propensity-score comparison (multiple site)</td>
<td></td>
</tr>
<tr>
<td>Masubuchi et al. (24)</td>
<td>2019</td>
<td>Lap</td>
<td>40 [50]</td>
<td>222 vs. 204 (0.24)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>10 vs. 10 (1)</td>
<td>N/A</td>
<td>11 vs. 12 (0.57)</td>
<td>Retrospective propensity-score comparison (single site)</td>
<td></td>
</tr>
</tbody>
</table>

MIS, minimally invasive surgery; SSI, surgical site infection; AL, anastomotic leak; IH, incisional hernia; SBO, small bowel obstruction; LOS, length of stay; N/A, data not included/provided in study.

Literature describing the intracorporeal technique for left sided colorectal resections has recently emerged and is still being refined. Prior to the current study, there were no large, randomized, multi-institutional studies comparing intracorporeal and extracorporeal techniques for left-sided colorectal resections. This is an important area for future study to determine which technique provides the best outcomes for patients undergoing these procedures.
Meta-analysis of right and left colectomies

Emile et al. published a systemic review and meta-analysis that included twenty studies (18 right colectomy and 2 left colectomy) comparing IA versus EA for minimally invasive colectomies. Their analysis included 3,745 patients and confirmed similarly favorable results for the IA group including shorter hospital length of stay, decreased short and long term complication rates, fewer anastomotic leaks, surgical site infections, and incisional hernias (25). Interestingly, the operative time difference between IA and EA groups in this analysis only varied by 13 minutes, suggesting that operative times for the IA approach may improve with experience (25).

There is a paucity of literature comparing robotic and laparoscopic minimally invasive approaches for IA and EA. Studies comparing robotic IA with laparoscopic EA showed favorable outcomes for the robotic approach but it may have been the IA technique rather than the robotic approach responsible for the favorable outcomes (26,27). IA advantages are demonstrated by surgeons capable of minimally invasive suturing techniques. IA with the robotic platform is likely available to more surgeon skill sets than laparoscopic IA because of robotic articulating instruments and ergonomic advantages (9).

Summary

The intracorporeal anastomosis for right and left hemicolecotomies has several outcomes advantages when compared to the extracorporeal technique. These intracorporeal technique advantages include the ability to perform the resection and anastomosis without traction injury to bowel remaining in-situ or the need to lengthen the extraction site incision delivering the specimen under tension, and the ability to use an off-midline extraction site incision with less risk for incisional hernias. Further advancements in minimally invasive technology may allow further refinements in intracorporeal techniques that may convey other outcomes advantages.

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Footnote

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