Role of Minimally Invasive Surgery in the Reoperative Abdomen or Pelvis

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Abstract

Laparoscopy has become widely accepted as the preferred surgical approach in the management of benign and malignant colorectal diseases. Once considered a relative contraindication in patients with prior abdominal surgery (PAS), as surgeons have continued to gain expertise in advanced laparoscopy, minimally invasive approaches have been increasingly incorporated in the reoperative abdomen and pelvis. Although earlier studies have described conversion rates, most contemporary series evaluating the impact of PAS in laparoscopic colorectal resection have reported equivalent conversion and morbidity rates between reoperative and non-reoperative cases, and series evaluating the impact of laparoscopy in reoperative cases have demonstrated improved short-term outcomes with laparoscopy. The data overall highlight the importance of case selection, careful preoperative preparation and planning, and the critical role of surgeons' expertise in advanced laparoscopic techniques. Challenges to the widespread adoption of minimally invasive techniques in reoperative colorectal cases include the longer learning curve and longer operative time. However, with the steady increase in adoption of minimally invasive techniques worldwide, minimally invasive surgery (MIS) is likely to continue to be applied in the management of increasingly complex reoperative colorectal cases in an effort to improve patient outcomes. In the hands of experienced MIS surgeons and in carefully selected cases, laparoscopy is both safe and efficacious for reoperative procedures in the abdomen and pelvis, with measurable short-term benefits.

Keywords

- ▶ reoperative
- ▶ minimally invasive surgery
- ▶ colon and rectal surgery
- ▶ previous abdominal surgery

Since the first description of laparoscopic-assisted colectomy in 1991, minimally invasive surgery (MIS) has become widely accepted as the preferred approach for the surgical management of the majority of both benign and malignant colorectal pathologies. Relative to traditional open surgery, multiport laparoscopy has been shown to improve short-term postoperative outcomes with significantly lower intraoperative blood loss, reduced postoperative pain scores, shorter length of hospital stay, faster recovery, reduced morbidity, and mortality.^{1–5} Additionally, several large randomized controlled trials including the COST (Clinical Outcome of Surgical Therapy), CLASICC (United Kingdom Medical Research Council Trial of Conventional versus Laparoscopic-assisted Surgery in Colorectal Cancer), COLOR I (European Colon Cancer

Laparoscopic or Open Resection), and COLOR II trials have demonstrated equivalent short- and long-term oncologic outcomes of laparoscopic colon resection and have confirmed the oncologic safety of laparoscopic total mesorectal excision (TME) with respect to surgical margins, lymph node harvest, and completeness of TME resection.^{5–14} While randomized controlled trials comparing laparoscopic, and open colon and rectal resections have shown equivalent morbidity including comparable incidence of infectious, anastomotic, and incisional complications,^{3,5–8} conversion rates for laparoscopic colorectal resection have ranged from 5% to as high as 34% for TME rectal resections.^{9–14} Unplanned conversion typically reflects technical difficulties to complete safe dissection as a result of complex anatomy, pathology, adhesions, visceral

obesity, or occurrence of intraoperative complications such as bleeding and/or organ injury.^{15,16} Conversion rates are also impacted by the surgeon's MIS experience and technical expertise with laparoscopic techniques, hence reflecting individual surgeons' learning curve.¹⁷ Regardless of the rationale for conversion, converted cases are associated with worse outcomes, including increased operative blood loss, anastomotic leak rate, reoperation, and length of hospital stay.^{17–19} In addition, conversion during colorectal cancer resection may result in worse oncologic outcomes relative to both laparoscopic and open surgery.²⁰ As a result, early studies investigating outcomes of MIS for benign and malignant conditions relative to open surgery typically excluded patients with prior abdominal or pelvic surgery (COLOR and COLOR II trial) and other conditions precluding safe completion of laparoscopic procedures such as emergency surgery, intestinal obstruction, and body mass index (BMI) greater than 30.^{5,8–10,21} As the worldwide experience with laparoscopy has continued to mature, an increasing proportion of surgeons are gaining or have gained expertise in MIS and are well beyond their learning curve, as reflected by lower overall conversion rates in contemporary series on laparoscopic colorectal procedures, including rectal cancer resection.^{9,10,13,14} Simultaneously, with the introduction of MIS technologies, such as hand-assisted technique and surgical robotics, aimed to help reduce conversion rates and shorten the learning curve, MIS techniques have been increasingly adopted in the management of complex colorectal diseases, including reoperative abdominal and pelvic surgery.

While the use of MIS in reoperative cases is justified by anticipated short-term benefits from MIS techniques including reduced incisional pain, faster resolution of ileus, shorter length of hospital stay, and faster recovery, this must be balanced with higher costs related to longer operative time, potentially higher conversion rates and increased intraoperative complications resulting from performing more complex procedures in an often hostile abdomen and pelvis. In a retrospective review of 1,000 consecutive laparoscopic colorectal procedures where 42.3% of the patients had prior abdominal surgery (PAS), Franko et al reported a significantly higher rate of conversion in reoperative cases (19.6 vs. 11.4%). Although the rate of inadvertent enterotomy in reoperative cases was only 1.4%, it was significantly higher than in non-reoperative cases (0.2%).²² Ultimately, reoperative surgery using MIS may play a role in a select group of patients in whom benefits of a minimally invasive approach outweigh the surgical risks. It should be used in centers with expertise in complex laparoscopic procedures, following careful preoperative planning and input from multidisciplinary specialists.

Adoption of Minimally Invasive Techniques in Colorectal Surgery and Conversion Rates

Minimally invasive approaches for reoperative colorectal surgery have not been widely adopted, and the published experience with laparoscopic and robotic approaches in

reoperative abdominal and pelvic surgery is limited to small institutional case series and specific colorectal pathologies and generally suffer from surgeon and selection biases. A major contributor to low adoption of MIS for reoperative cases has been slow adoption of laparoscopy in general, as well as highly variable laparoscopic skills and learning curves.

While adoption of laparoscopy in colorectal surgery has significantly increased over the last two decades, open surgery remains the predominant approach with 33 to 50% of elective colectomies being performed laparoscopically in the United States.^{23–25} A review of the National Inpatient Sample database noted an increase in the proportion of colorectal cases performed using laparoscopy on from 13.8% in 2007 to 42.6% in 2009 ($p < 0.01$), reflecting the use of laparoscopic colorectal procedural codes in 2008.²⁶ More specifically, adoption of laparoscopic technique was highest for benign diverticular disease and colon cancer and lowest for rectal cancer (49.6 vs. 45 vs. 19.5%; $p < 0.001$),²⁶ thus reflecting the technical complexity of completing TME using a laparoscopic approach. A more contemporary national database review of academic medical centers including 85,712 patients undergoing colon resection between 2008 and 2011 demonstrated an increase in the use of laparoscopy from 37.5 to 42.2% over the study period, with a 15.8% overall conversion rate.²⁷ The increase in utilization of laparoscopy was observed for both benign and oncologic indications, but significant variations were noted in utilization of laparoscopy based on region and hospital size.²⁷ Similarly, a 2006–2011 ACS-NSQIP review of 94,464 colectomies demonstrated use of laparoscopy in 46.7% of the cases, with a 5.8% overall conversion rate.²⁸ On multivariate analysis, age more than 50, BMI >30 , ASA (American Society of Anesthesiologists) class 3 or higher, smoking, ascites, and weight loss were all significant predictors of conversion to open surgery.²⁸ While neither of those large databases specifically analyzed the impact of prior abdominal or pelvic surgery on utilization of laparoscopy or incidence of conversion, other studies have specifically evaluated the impact of PAS on conversion rates. In their National Inpatient Sample database review of 207,311 patients undergoing laparoscopic colorectal resection between 2009 and 2010, Masoomi et al reported a 16.6% conversion rate with highest conversion rates during laparoscopic proctectomy (31.4%) and laparoscopic resection for Crohn disease (CD; 20.2%). Multivariate regression analysis identified the need for laparoscopic lysis of adhesions, which occurred in 14.9% of patients, as an independent risk factor for conversion. In this study, lysis of adhesions was a surrogate for PAS.¹⁹

Several recent technologies and techniques have been proposed to facilitate completion of laparoscopic procedures and reduce conversion rates. The use of the robotic platform in colorectal surgery, which was first described in 2002, provides several advantages over laparoscopy, including improved ergonomics, three-dimensional vision and camera stability, surgical dexterity with full-wristed instrumentation, and stable tissue retraction through the assistance of robotic arms. Wide adoption of robotic techniques has been limited by the prohibitive costs of the robot, longer operative time, and long learning curve.^{29,30} A National Inpatient

Sample review demonstrated an increase in utilization of robotic colorectal surgery in the United States from 1.88% in 2009 to 3.66% in 2010.³¹ Although overall utilization of robotics remains low, the rate of robotic rectopexy and TME procedures for rectal prolapse and rectal cancer, respectively, has been increasing. The majority of large single center series comparing robotic and laparoscopic approaches for colorectal resection have suggested longer operative time, similar short and long-term outcomes including oncologic outcomes, but significantly lower conversion rates, when specifically comparing robotic to laparoscopic TME.^{31–34} The 2013 ACS NSQIP analysis demonstrated that among 141,477 minimally invasive colorectal procedures reported, 2.8% of colon resections versus 10.8% of rectal resections were performed robotically. The conversion rate was 10 versus 13% with the robotic approach ($p < 0.001$), with significantly reduced length of hospital stay relative to laparoscopic surgery.³⁵

Another technology that was developed in an effort to increase the completion rate of laparoscopic-assisted colorectal procedures is handassistance during laparoscopic surgery (HALS). By placing a hand through an airtight abdominal port into the abdomen during laparoscopic resections, HALS allows the surgeon to maintain tactile sensation while maintaining the benefits of conventional laparoscopic surgery and lower conversion rates for complex cases.^{36–39} HALS was never widely adopted as it was only associated in modest benefits, but higher hernia formation and surgical site infection rates relative to laparoscopy.^{40,41} Additionally, there has been concern that this technique may prevent the surgeon from fully developing an advanced laparoscopic skill set.

The role of robotics and HALS in facilitating or hindering reoperative abdominal and pelvic surgery is unclear. Although PAS is not considered a contraindication to a laparoscopic, robotic, or HALS approach, the potential impact of those technologies on conversion rates or other postoperative outcomes has not been specifically evaluated. There is paucity of published data comparing minimally invasive modalities with respect to safety, efficacy, and potential benefit for reoperative colorectal surgery. In particular, no study has evaluated the potential role of robotic surgery in reducing the risk of conversion in reoperative colorectal surgery. Ultimately, it is the training and expertise of the surgeon that should be the driving factor when selecting the most appropriate and beneficial approach for reoperative colorectal surgery.

Reoperative Colorectal Surgery: Surgical Indications and Outcomes

Given the unequivocal clinical benefits of the laparoscopic approach for the majority of abdominal and pelvic procedures, a history of prior abdominal or pelvic surgery no longer constitutes a contraindication for reoperative laparoscopy. However, a history of PAS, particularly when performed through an open approach, in the emergency setting, or when complicated by intra-abdominal bleeding or sepsis, is likely to increase the amount of postoperative adhesion formation, increase the technical complexity of reoperative pro-

cedures, and require conversion to open surgery. In addition to careful case selection, including preoperative planning, medical optimization of patients, and meticulous surgical technique, sound clinical judgment and early recognition of risks of and actual injury with prompt conversion to open surgery is essential to minimize adverse events and worse outcomes.⁴²

Although PAS is often considered a risk factor for higher conversion rates and worse perioperative outcomes during minimally invasive colorectal surgery, the literature has not consistently supported this assertion. The results of 12 studies that specifically addressed the impact of prior abdominal procedures on successful completion and outcomes of laparoscopic reoperative colorectal surgery are summarized in **Table 1**. These studies include comparative, case-controlled, and observational studies.^{22,43–53} No study demonstrated a significant difference in operative blood loss or length of stay (LOS) associated with reoperative surgery. Three studies demonstrated an increased conversion rate in patients with previous abdominal surgery,^{22,44,45} two studies found PAS to be associated with increased operative time,^{44,46} and one study found a higher morbidity rate with PAS.⁵² Published data regarding conversions rates during laparoscopic reoperative surgery have been variable with rates ranging from 5.2 to 26.1% across studies evaluating a broad range of colorectal procedures in patients with various types of prior abdominal of pelvic procedures ranging from appendectomy and cholecystectomy, to Cesarean section (C-section), to major colorectal resections.^{19,54,55} The data from studies examining outcomes from reoperative laparoscopic surgery with respect to conversion rate, operative time, bleeding complication, morbidity, and length of stay are summarized in **Table 1**.^{22,43–53}

Fewer studies have investigated outcomes of reoperative robotic colorectal surgery, and there are no comparative or case-controlled studies. Reoperative robotic surgery has been reported to be safe in the urologic, bariatric, and gynecologic literature for procedures such as pediatric pyeloplasty, partial nephrectomy, radical prostatectomy, Roux-en-Y gastric bypass, and radical hysterectomy.^{56–60} Several studies evaluating robotic surgery for colorectal pathology have reported inclusion of patients with previous abdominal surgery but did not specifically address the impact that prior abdominal procedures had on procedure completion or conversion rate.^{61–63}

Overall, minimally invasive techniques have been routinely used in the elective setting for reoperative colorectal procedures related to benign and malignant conditions such as inflammatory bowel disease (IBD), diverticular disease, adhesive bowel obstruction, stoma creation and reversal, rectal prolapse procedures, and colorectal cancer. In addition, an increasing number of reports have reported on the feasibility and safety of laparoscopy in the management of colorectal emergencies including reoperative intervention for early postoperative complications.

Reoperative Minimally Invasive Surgery for Inflammatory Bowel Disease

CD is associated with an 80% lifetime risk of requiring surgical intervention and 50% risk of subsequent reoperation within

Table 1

Authors(year)	Number of patients	Conversion rate (%)	Operating time (min)	Blood loss (mL)	Morbidity (%)	Length of stay (d)
Hamel et al ⁵³ (2000)	PAS= 36 NPAS= 49	17 12	151 148	– –	47 37	6.8 7.6
Law et al ⁴³ (2005)	PAS= 84 NPAS= 211	17.8 11.4	180 170	125 150	16.7 20.8	7 7
Arteaga González et al ⁴⁵ (2006)	PAS = 27 NPAS = 59	26.1 5.1	223 199	213 181	39.1 38.9	6.3 7.6
Franko et al ²² (2006)	PAS= 347 NPAS= 473	19.6 11.4	159 158	180 153	– –	– –
Vignali et al ⁴⁶ (2007)	PAS= 91 NPAS= 91	16.5 8.8	218 192	181 153	25.3 23.1	9.9 9.1
Offodile et al ⁴⁷ (2008)	PAS= 191 NPAS= 223	17 15	186 176	230 206	– –	7 6.3
Barleben et al ⁴⁸ (2009)	PAS= 55 NPAS= 0	14.5 –	– –	– –	– –	– –
Fukunaga et al ⁴⁹ (2011)	PAS= 192 NPAS= 415	5.2 2.6	NS NS	NS NS	16 14	– –
Maggiori et al ⁴⁴ (2013)	PAS= 167 NPAS= 200	22 13	229 216	– –	22 19	10 9
Naguib et al ⁵¹ (2012)	PAS= 68 NPAS= 113	13.2 10.6	233.2 216.5	– –	– –	4 4.5
Yamamoto et al ⁵⁰ (2013)	PAS= 580 NPAS= 1121	12.4 10.2	242.5 244	– –	25.3 23.3	19 18.8
Aytac et al ⁵² (2015)	PAS= 50 NPAS= 50	16 8	211 192	158 184	54 20	– –

Abbreviations: NPAS, no prior abdominal surgery; NS, nonsignificant; PAS, prior abdominal surgery.

Note: Bold values are statistically significant.

10 years.⁶⁴ Pinto et al performed a retrospective comparison of 80 patients who underwent primary laparoscopic resection for CD and 50 patients who underwent laparoscopic resection for recurrent CD.⁶⁵ The majority of Crohn resections (82%) consisted in ileocolic resections (primary vs. secondary or tertiary). Reoperative laparoscopic resection was associated with a higher rate of conversion to open surgery, although not statistically significant (32 vs. 18.7%). No differences in intra- or postoperative complications or LOS were noted between the two groups.⁶⁵ Similar results were reported by Aytac et al who performed a case matched study of 52 patients with recurrent CD, 26 of which treated with laparoscopic reoperative surgery and 26 treated using an open approach.⁵² A statistically significantly lower wound infection rate was noted in the laparoscopic reoperative group (8 vs. 12%). Other variables such as operative time, blood loss, morbidity, and LOS were similar between the groups.

In contrast to CD, fewer patients with ulcerative colitis (UC) require operative intervention during their lifetime with the estimated risk of 20%.⁶⁴ The role of laparoscopy in restorative proctocolectomy (RPC) has been extensively studied and found to be efficacious not only for a two-stage approach, but also for a three-stage reoperative RPC^{66,67} when laparoscopic ileal pouch-anal anastomosis (IPAA) follows laparoscopic or open

subtotal colectomy. Pandey et al prospectively compared 68 patients with UC who underwent three-stage RPC with IPAA using a laparoscopic approach for stage 1 and 2, to 50 patients who underwent a two-stage laparoscopic approach.⁶⁶ Although patients receiving aggressive medical therapy and with poorly controlled disease were more likely to undergo three-stage RPC, the incidence of infectious complications was significantly higher in the two-stage RPC group (38.2 vs. 21%). There were no conversions in either group, and overall complication rates were otherwise similar.⁶⁶

A recent meta-analysis of 27 comparative studies of 2,428 patients undergoing open or laparoscopic one-, two-, or three-stage RPC for UC, dysplasia, and malignancy demonstrated that minimally invasive RPC, including laparoscopic-assisted, hand-assisted, and totally laparoscopic ileoanal pouch creation, resulted in longer operative time, shorter length of hospital stay, lower wound infection rate, and similar long-term pouch function than open RPC.⁶⁷ Most importantly, although the meta-analysis did not specifically analyze the outcome of laparoscopic one- or two-stage RPC relative to three-stage RPC, the overall conversion rates was only 3.9%, ranging from 0 to 25%. Conversion rates were lowest in more contemporary studies, likely reflecting improved experience, mastery of the learning curve, and improved patient selection.⁶⁷

Although no study has directly compared robotic versus open IPAA, a small case-matched study ($N = 34$) comparing robotic versus laparoscopic proctectomy with IPAA for IBD reported no conversion in either group and no differences in operating room (OR) time, perioperative outcomes, and functional outcomes.⁶⁸

Reoperative Minimally Invasive Surgery for Diverticular Disease

Regarding the elective management of diverticular disease, many studies have demonstrated the benefits of a minimally invasive approach to surgery for diverticular disease including lower postoperative morbidity, earlier return of bowel function, and shorter LOS.⁶⁹ Few studies have addressed the impact of previous abdominal surgery on outcomes of minimally invasive reoperative surgery for diverticular disease. The Sigma trial, a multicenter, double blinded, randomized control trial comparing laparoscopic to open sigmoid resection for diverticular disease in a 104 patients, specifically excluded patients with prior colorectal resection and a history of previous laparotomy other than for gynecologic or obstetrical surgery.⁷⁰ Likewise, the randomized multicenter laparoscopic peritoneal lavage versus sigmoidectomy for perforated diverticulitis trial (Ladies trial) that compared 47 versus 43 patients randomized to laparoscopic lavage versus sigmoidectomy only included 9 versus 7% of patients with prior laparotomy.⁷¹

Reoperative Minimally Invasive Surgery for Stoma Reversal

Stoma creation and reversal are common indications for minimally reoperative surgery. Fecal diversion for failed colorectal anastomoses, recurrent CD, ileal pouch dysfunction, and fecal incontinence can typically be performed laparoscopically with significant clinical benefits over an open approach. In a retrospective case-matched series comparing 63 laparoscopic diversion (24 colostomy, 19 ileostomy) to 133 open fecal diversion (37 colostomy, 96 ileostomy) in patients with similar incidence of PAS (49 lap vs. 65% open), the laparoscopic approach was associated with significantly lower blood loss, shorter LOS, lower incidence of ileus, and readmission rates than the open approach. There were no conversions in the laparoscopic diversion group.⁷²

Regarding stoma reversal, laparoscopic ileostomy reversal has recently been proposed as an alternative to conventional open closure through the ileostomy site, with the benefit of laparoscopic hernia repair or prevention with mesh placement. In a retrospective cohort study comparing laparoscopic versus open ileostomy reversal in 53 patients versus 80 patients whose index case was performed either open, laparoscopically, or robotically,⁷³ the laparoscopic reversal group was associated with significantly longer operative time due to adhesiolysis and concurrent stoma site mesh reinforcement for hernia prevention. No conversion occurred in the laparoscopic group and no significant differences were noted in blood loss, LOS, or overall morbidity between the groups.⁷³

Unlike laparoscopic ileostomy closure, laparoscopic Hartmann's reversal has significant benefits over the open approach. In a systematic review of 35 studies on Hartmann's reversal in a total of 6,249 patients, 396 were reversed laparoscopically and 5,853 using an open approach.⁷⁴ Overall mean conversion rate was 12.6% (range 7–22%) with the most common reason for conversion being the lack of visualization due to dense adhesions (80%). There were significant differences in operative time or mortality between groups but the laparoscopic approach was associated with a shorter LOS (6.9 vs. 10.7 days) and lower morbidity (12.2 vs. 20.3%), mainly accounted for by a reduced rate of wound infection (10.8 vs. 14.2%). These benefits of a laparoscopic approach for Hartmann's reversal were recently confirmed in a study by Maitra et al where retrospective review of 45 cases of laparoscopic versus 50 cases of open Hartmann's reversal was compared.⁷⁵ Despite a relatively high conversion rate of 29%, with converted patients being analyzed on an intent to treat basis, the laparoscopic approach still resulted in a significantly shorter LOS (6.8 vs. 14.9 days) and lower overall morbidity (8.9% vs. 26%) relative to the open approach.⁷⁵

Reoperative Minimally Invasive Surgery for Colorectal Resections

Laparoscopic colectomy after previous abdominal surgery has been widely reported in case-matched and comparative studies to be safe and overall not associated with higher rates of conversion to open surgery.^{46–48,53,76} Several large series of laparoscopic resections for colorectal neoplasia have demonstrated no significant increase in conversion rates associated with a history of PAS. Early reports including a 2008 retrospective review of 121 consecutive patients who underwent laparoscopic colorectal cancer resection demonstrated longer operative time (175 vs. 155 minutes) but equivalent conversion and perioperative complication rate in patients with PAS.⁷⁶ Offodile et al compared outcomes of 191 patients with and 223 patients without PAS undergoing laparoscopic right hemicolectomy for neoplasia.⁴⁷ Conversion rates (17 vs. 15%), operative time, blood loss, specimen size, and number of harvested nodes did not significantly differ between the prior (patients in Offodile study who had previous right hemicolectomy) and no PAS group. However, a higher incidence of wound infection was observed in the group with PAS.⁴⁷

Unfortunately, most of these comparative studies are limited by their retrospective design, lack of matching between cohorts, and inherent selection biases, as reflected by significant differences in demographics of patients and BMI.^{46–48,53,76} In addition, when evaluating the impact of PAS on conversion rates, the studies do not distinguish between type and number of abdominal procedures (hysterectomy, appendectomy, cholecystectomy, tubal ligation, colorectal resection, or C-section) and method of prior surgery (open, laparoscopic, or other). One recent study by Haksal et al evaluated outcomes of laparoscopic sigmoid and rectal resections in 252 patients with no prior abdominal surgery (NPAS) and 25 patients with PAS via prior vertical laparotomy with no significant differences in OR time, conversion rates

(7.9 vs. 16%), or any other postoperative outcomes.⁷⁷ Besides the small size of the PAS cohort, the study did not distinguish between types of PAS.

With respect to the method of PAS, in a retrospective analysis of 55 patients with a history of prior open, laparoscopic, or a combination of approaches and who subsequently underwent laparoscopic colorectal resection for benign and malignant etiologies, a significantly higher conversion rate was noted in patients who had a history of prior open abdominal procedures relative to patients with prior laparoscopic colorectal procedures (16.7 vs. 12.5%) with the highest rate of conversion noted in patients with a history of prior left colectomy.⁴⁸ In a 2007 case-controlled study of 91 patients with PAS who underwent a variety of laparoscopic resections, when patients were matched with 91 historical controls with no PAS, PAS was associated with significantly longer OR time (218 vs. 192 minutes) but no significant differences in postoperative outcomes. The conversion rate, although higher in the PAS group, did not reach statistical significance (16.5 vs. 8%), but again the differential impact of various types of abdominal surgery on specific risk for conversion was not assessed.⁴⁶

Few studies have investigated the impact of previous abdominal or pelvic surgery on the ability to perform minimally invasive proctectomy for rectal cancer. Most series have reported outcomes of colon and/or rectal cancer resection and included patients with PAS. One such study by Kang et al has reported on the outcome of robotic rectal cancer resection in 389 patients of which 13% had PAS. Despite an exceedingly low conversion rate (1%), on univariate and multivariate analyses, a history of PAS was independently associated with incidence of postoperative complications, and a significantly higher rate of postoperative ileus was also noted in the PAS group.⁷⁸

A scarce number of case series have evaluated the feasibility, safety, and potential benefit of minimally invasive approaches for complex reoperative oncologic interventions for residual, or recurrent colon or rectal cancer. Only three series have described a laparoscopic approach for recurrent colorectal cancer in a total of 29 patients, including 18 rectal cancers.^{79–81} Conversion to open surgery in that series was needed in five cases (17.2%) primarily as a result of dense adhesions and ambiguous tissue planes around recurrent tumors. Relative to cohorts who underwent open salvage resection, the laparoscopic approach resulted in similar oncologic and perioperative outcomes.^{80,81} In the largest study published to date on laparoscopic resection for locally recurrent rectal cancer comparing 13 laparoscopic to 17 open salvage resections, the laparoscopic approach was associated with significantly longer OR time but equivalent R0 resection rate (100 vs. 94%) and postoperative outcomes, with only one case requiring conversion.⁸¹ Another recent series described nine patients who underwent laparoscopic lateral pelvic lymph node dissection (LPLD) for isolated local recurrence in the lateral pelvic lymph nodes after surgery for rectal cancer. Enbloc resection of the internal iliac artery, seminal vesicle, and/or pelvic plexus could be performed with R0 resections in all patients with no conversion and acceptable morbidity rate (33%).⁸²

Overall, the consensus among the aforementioned authors is that a minimally invasive approach for recurrent rectal cancer has the advantage of providing superior visualization and exposure but requires significant longer operating time and expertise with complex laparoscopic techniques to manage dense adhesions from prior resections. This approach should not be routinely applied for extended multivisceral resection or pelvic exenteration procedures but limited to resection of localized recurrences limited to anastomotic recurrences and salvage.

Reoperative Minimally Invasive Surgery for Adhesiolysis

Although abdominal adhesions can form after a variety of inflammatory processes, the most common etiology is prior surgical intervention. Adhesiolysis is often required at the start of most reoperative colorectal surgery to gain entry to the peritoneal cavity and establish a working space for further planned procedures. A large body of literature supports the safety and benefits of laparoscopic adhesiolysis for adhesive small bowel obstruction, with demonstrated improved short-term outcomes. Experience with laparoscopic techniques is an essential requirement to complete reoperative colorectal procedure using a minimally invasive approach. Davies et al retrospectively reviewed 102 patients at a single institution presenting with a small bowel obstruction, of which the lysis of adhesions was approached laparoscopically in 38 patients and open in 64 patients.⁸³ A history and frequency of previous abdominal operations was not statistically different between the groups. Those treated laparoscopically were found to require fewer intensive care unit admissions and shorter LOS. A trend was noted toward a decreased incidence of surgical site infections, but was not significant.

Reoperative Minimally Invasive Surgery for Colorectal Emergencies

Until recently, laparoscopy was relatively contraindicated in the emergency setting such as the management of acute small or large bowel obstruction, perforated viscus or diverticulitis, toxic infectious or inflammatory megacolon, and reoperation for postoperative complications. There has been a growing trend toward routine laparoscopic exploration and the management of colorectal emergencies as reflected by wider adoption of laparoscopic lavage in Hinchey IV perforated diverticulitis.⁸⁴ A systematic literature review of 22 studies evaluating outcomes of emergency laparoscopic colorectal resections relative to open cohorts demonstrated improved short-term outcomes with a minimally invasive approach as demonstrated by reduced LOS and lower complication rates.⁸⁵ While these data reflect major selection biases and lack of consistent indications/contraindications for a laparoscopic approach, it still highlighted a remarkably low 3% median conversion rate (range, 0–13.5%) and growing trend toward adoption of laparoscopy in the emergency setting. This trend also applied to the management of colorectal emergencies in patients with PAS. Included in the review,

four studies described the use of laparoscopy in 85 patients with colorectal emergencies, 32 of which in patients with PAS, with only one conversion to open surgery.^{86–89}

With regard to reoperative intervention for the management of surgical complications, it is clear that reoperation via laparotomy would negate all the benefits of a laparoscopic approach at the index operation. There have been a rising number of reports demonstrating the safety of early reoperative laparoscopy to evaluate abdominal pain and sepsis and manage bile leaks, iatrogenic perforations, anastomotic leakage, bleeding, sepsis, and bowel obstruction following elective laparoscopic cholecystectomy, bariatric procedures, and incisional hernia repair, with conversion rates ranging from 10 to 13.5%.^{90,91} Recent reports have also described the use of MIS in early reoperative intervention for complications following elective colorectal surgery.^{92,93} Cuccurullo et al recently described the experience of surgeons with extensive laparoscopic experience (≥ 50 prior laparoscopic colorectal resections) with using relaparoscopy in the management of postoperative complications following elective MIS colorectal procedures. The authors described attempting relaparoscopy in 84 out of 102 patients requiring reoperation for postoperative complications. All 84 patients were deemed eligible for relaparoscopy based on hemodynamic stability, and laparoscopic reoperation was successful in managing peritonitis, bleeding, and small bowel obstruction in 94% of the cases.⁹⁴ Reoperative laparoscopic procedures consisted of diagnostic laparoscopy, peritoneal lavage and drainage, repair of anastomotic leak or perforation, diverting stoma creation, repair of ureteral injury, lysis of adhesions, reduction of internal or port-site hernia, control of bleeding, and small bowel resection. Conversions were required to manage colonic ischemia, fecal peritonitis, and lack of working space.

Patient Selection

Appropriate patient selection is paramount to successful completion of a reoperative MIS. Patient suitability is dependent upon the intended procedure as not all MIS colorectal operations carry the same risk profile. There are relatively few absolute contraindications to a minimally invasive approach in either an elective or emergent setting. Due to the ensuing fluid shifts and extreme positioning required intraoperatively, patients with severe hemodynamic derangement (hypotension defined as systolic blood pressure <90 mm Hg), septic shock, uncorrectable coagulopathy, poor pulmonary reserve, uncorrected hypercapnia, and the inability to tolerate a laparotomy due to advanced cardiomyopathy are not candidates for MIS.⁹⁵ All other contraindications can be classified as relative including preoperative conditions that may preclude safe abdominal access and exposure during laparoscopy. These relative contraindications include limited working domain, as in the setting of massive small or large bowel obstruction, or dense adhesions, presence of diffuse peritonitis (fecal or purulent), extensive bowel ischemia, or major intra-abdominal bleeding, may preclude adequate control using a pure laparoscopic technique. Patients with relative contraindications should be evaluated on a case-by-

case basis to determine the appropriateness of MIS. In this setting, a diagnostic laparoscopy, even with a low expectation of completing the case minimally invasively, still has the benefit of facilitating prompt assessment and diagnosis and serves as a useful adjunct to laparotomy.

With regard to medical optimization prior to reoperative surgery, particularly using a minimally invasive approach, a thorough medical history must be obtained with particular focus on pulmonary status, cardiovascular health, and renal function. Since laparoscopic reoperative colorectal surgery typically results in increased procedural time when compared with open surgery, patients should be medically optimized to tolerate large fluid shifts and the stress of prolonged anesthesia. Cardiac and pulmonary evaluations are recommended for patients with a known history of organ dysfunction or systemic diseases. All laparoscopic colorectal procedures are considered intermediate cardiac risk and, as such, patients with an active cardiac condition or designated American Heart Association class 1 are recommended to undergo preoperative stress testing.¹⁶ When appropriately selected, reoperative minimally invasive colorectal surgery has been proven to be safe and beneficial, even for relatively vulnerable populations such as the elderly and morbidly obese patients.

Preoperative Planning

Patients presenting for elective reoperative surgery should be not only medically and nutritionally optimized prior to the procedure, but also temporally optimized from the previous abdominal operation. Adhesions can form within the first week after surgery and are initially more vascular and dense, making immediate reentry into the abdomen more difficult.⁹⁶ If the clinical situation permits, a delay in reoperative surgery by 3 months may allow the adhesions to thin and be less vascular, which may facilitate safe abdominal entry and adhesiolysis.⁹⁷ Deferring reoperative surgery for an appropriate length of time also allows for restoration of physiologic and functional capacity, repletion of nutritional stores, weaning of steroid medications, and completion of adjunct treatment such as adjuvant or neo-adjuvant treatment.^{98–100} Consideration should be given to marking patients preoperatively for potential stoma creation both in the elective and emergency reoperative setting. In addition, in complex MIS reoperative pelvic cases, intraoperative consultation with urology, gynecology, orthopedics, and/or vascular surgery should be coordinated if pelvic exenteration is anticipated or when assistance with ureteral or other pelvic organ dissection is anticipated.

Every effort should be made to identify risk factors for conversion prior to reoperative colorectal surgery. This permits improved preoperative and intraoperative planning and better preparation of patients with regard to realistic expectations from reoperative surgery. Conversion from laparoscopic to open during colorectal surgery has not only been shown to be result in worse morbidity and mortality relative to nonconverted cases and open cases,^{18,19,54,55} but postoperative outcomes are also improved if conversion occurs within the first 30 minutes of the case and if conversion is preemptive rather reactionary to complication.⁵⁵ This again highlights the importance of

accurate preoperative risk assessment, expectations, and perioperative planning.

Details of the number, type, and method of prior abdominal procedures can help predict the risk of intraoperative complications and/or conversion associated with reoperative minimally invasive colorectal surgery. Procedures that can be anticipated to be associated with a high risk of adhesion formation include open surgery via laparotomy, adhesiolysis, prior ventral hernia repair with mesh,¹⁰¹ bowel perforation, postoperative anastomotic leakage, intra-abdominal bleeding, or sepsis.

Although no study has specifically addressed the impact of BMI in the success of reoperative colorectal surgery, there is extensive data evaluating the impact of BMI on perioperative outcomes during laparoscopic colorectal resections. A recent systematic review and meta-analysis demonstrated that obesity, defined as a BMI >30 kg/m², is associated with longer operative time and higher rates of conversion to open surgery in patients undergoing laparoscopic colorectal resection.¹⁰² Conversion, in the setting of significant visceral obesity, typically occurs from difficulties in achieving adequate exposure and identifying correct tissue planes. Although some studies found evidence of increased postoperative morbidity in obese patients, there was no evidence of impact on wound infection rate. The oncologic lymph node harvest and postoperative recovery of bowel function were also found to be comparable.¹⁰²

Preoperative Studies

After medical suitability for reoperative abdominal or pelvic reoperation has been determined, attention must be directed to the patients' detailed past surgical history with emphasis on the details of all prior procedures. The number of operations, types of procedures, location of prior incisions, and targeted anatomy of the proposed surgery should all be taken into account. Prior operative reports should be reviewed. Preoperative computed tomography scans, magnetic resonance imaging (MRI), and barium enema may be useful when planning a reoperative surgery to delineate complex anatomy and rule out fistulas, strictures, residual abscess, loss of abdominal domain, and accurately stage tumors. When preparing patients with CD for reoperation such as repeat ileocolic resection, takedown of enteric or enterocutaneous fistulas, careful mapping of areas of active disease with endoscopy, and/or magnetic resonance enterography are particularly valuable to guide safe laparoscopic entry into the abdominal cavity, confirm the feasibility of a laparoscopic approach, and plan the extent of the resection. Endoscopy is also routinely performed for preoperative planning prior to Hartmann's pouch reversal when performed using an open or minimally invasive approach.

Regarding the role of imaging in assessing and quantifying the extent of intra-abdominal adhesions, several authors have advocated for the preoperative localization of abdominal wall adhesions utilizing the noninvasive radiologic modalities of ultrasound and MRI.¹⁰³ These techniques rely on the identification of normal organ excursion with respiration, also known as visceral slide, along the abdominal wall. When an abdomi-

nal wall adhesion is present, it will reduce the ability of the organ to slide and can be detected by noninvasive means. In 1995, Caprini et al evaluated 30 patients scheduled for reoperative laparoscopic surgery with transabdominal ultrasound to identify adhesions. This was performed on the operating room table by either the surgeon or ultrasound technologist and confirmed the presence of adhesions via reduced visceral slide underlying visible abdominal wall scars. The knowledge of adhesion location assisted the surgeon to gain safe entry into the abdominal cavity and guided further port placement for adhesiolysis.¹⁰⁴ Lang et al demonstrated that functional CineMRI could be utilized to not only identify adhesions to the abdominal wall, but also to detect intra-abdominal organ to organ adhesions.¹⁰⁵ A recent review of the literature for the noninvasive radiologic detection of adhesions demonstrated that both modalities have a similar rate of sensitivity, specificity, and accuracy¹⁰⁶; however, this practice has not become widely adopted.

Reoperative MIS: Techniques

Avoiding Organ Injury: Gaining Abdominal Access

When selecting a method of abdominal entry for a minimally invasive reoperative colorectal procedure, it is important to consider the prior surgical history and the specific pathology that may complicate entry. Abdominal entry can be established via closed methods such as the Veress needle and optical trocar or open methods such as the Hasson technique and peek-port technique. Regardless of access technique, following pneumoperitoneum establishment and camera insertion, the visceral space below the site of entry must be examined for possible injury.

A large meta-analysis of 46 randomized controlled trials evaluating 13 laparoscopic entry techniques reported similar complication rates during entry between open and closed techniques.¹⁰⁷ Although the incidence of organ or vessel injury during closed technique was found to be low (0.18%), more than half of those injuries occurred in patients with PAS.¹⁰⁸ Another study found that entry with a Veress needle was responsible for more than 40% of all inadvertent enterotomies created during laparoscopic surgery.¹⁰⁹ This highlights the importance of careful selection of entry location on the abdominal and the use of caution during the access technique.

Due to the high likelihood of adhesion formation below previous abdominal scars, entry at these sites should be avoided if possible. Brill et al found that supraumbilical midline incisions had the highest association of omental and bowel adhesions when compared with other abdominal wall incisions.¹¹⁰ For this reason, the left upper quadrant, at Palmer's point, is considered to be a safe site of entry in patients with a history of previous surgery. Palmer's point is located 2 to 3 cm below the left costal margin in the midclavicular line, and the Veress needle should be inserted perpendicular to the skin.¹¹¹ The rate of injury from entry with Veress needle at this location is reported to be 0.4%.¹¹² Patients with previous splenic, gastric, or pancreatic surgery, hepatosplenomegaly, and portal hypertension should be

excluded, and caution is needed when using a Veress needle in patients with dilated large or small bowel from an obstructive process. If the left upper quadrant has previously been violated, alternative options for Veress needle entry include 3 cm lateral to the umbilicus and the right upper quadrant in the midclavicular line.

Open entry into the abdominal cavity was described by Hasson in 1971 as a method to enter the abdominal cavity safely under direct visualization, thereby minimizing the risk of organ and vascular injury.¹¹³ It is most commonly used for entry into the reoperative abdomen when blind entry is considered undesirable. As this technique utilizes access under direct visualization, it has historically delivered the safest route of entry.^{114,115} A variation of the direct trocar insertion, the optical trocar, allows for visualization during entry without prior pneumoperitoneum. The technique is to make a skin incision and then elevate the fascia against the advancing trocar which contains a 0-degree laparoscope for visualization. Although the use of this trocar allows for visualization during entry, it does not protect against organ injury during abdominal entry.¹¹⁶

The peek-port technique was developed to assess the feasibility of MIS in an abdomen thought to be at high risk for conversion to laparotomy due to the history of previous surgery. Before opening laparoscopic equipment, an 8-cm midline mini-laparotomy is made to assess the adhesive burden. If the abdomen is deemed suitable, then a hand-assisted port is placed and pneumoperitoneum established; if the abdomen is considered to be unsuitable for MIS, then the midline incision can be extended to a traditional exploratory laparotomy length. Read et al reported a 32% immediate conversion rate and a 5% delayed conversion rate utilizing this technique, thus avoiding the cost of opening laparoscopic equipment unnecessarily.¹¹⁷

Avoiding Organ Injury: Surgical Technique

Following safe laparoscopic abdominal entry, the ability to achieve satisfactory working domain and exposure of critical anatomy is assessed to determine if the procedure can be completed in a minimally invasive manner. Safe lysis of adhesions is an essential step in patients with a reoperative abdomen to permit adequate visualization, safe placement of subsequent ports, and identification of the targeted anatomy. This is first accomplished by clearing adhesions from the anterior abdominal wall to facilitate optimal placement of additional ports before turning attention to intra-abdominal adhesions to isolate and dissect the anatomy of interest. Adhesiolysis is a necessary aspect of any reoperative surgery and can be lengthy and tedious. Great caution must be taken to avoid inadvertent enterotomies and organ injury during laparoscopic lysis of adhesions. If encountered, prompt recognition and repair must be performed either laparoscopically, if feasible, or following conversion to open surgery. Several energy sources can be employed to facilitate lysis of adhesions including monopolar and bipolar electrocautery, ultrasonic shears, and sharp or blunt dissection. A level of vigilance for iatrogenic injury detection must be maintained while using these devices as electrothermal injury is the second most common cause of bowel injury during laparoscopy following entry trauma.¹¹⁸ Therefore, use of energy is

only recommended when a clear plane can be visualized between the adhesion and targeted anatomy. If the plane remains uncertain, techniques such as application of manual pressure on the anterior abdominal wall, downward traction on the adhesion with atraumatic endograspers, alterations in patient position, or blunt dissection may facilitate visualization. In the event that these manipulations are unsuccessful, the adhesions should be sharply divided without the assistance of electrocautery to reduce inadvertent thermal spread. A review of the literature did not reveal one energy type or device to be superior for laparoscopic colectomy or associated with a lower rate of inadvertent or missed organ injury.¹¹⁹

Blunt dissection is a useful adjunct to release thin adhesions or to create more space between organs and the abdominal wall for energy device use. The general principle of working from known to unknown structures in open surgery also applies to minimally invasive adhesiolysis to maximize safety during dissection. The camera position can be moved to another trocar for alternative viewing angles, as needed, to maintain optimal visualization of the dissection plane. When planes remain ambiguous or structure identification is difficult, conversion to open surgery may be necessary as partial or full-thickness bowel injuries are more likely occur. If recognized, the injury can be repaired intracorporeally or exteriorized for an open closure. As many as 40% of iatrogenic intestinal injuries during laparoscopic surgery are undiagnosed at the time of surgery, frequently discovered on postoperative day 3 or later.¹⁰⁹ A delayed recognition of injury can significantly increase morbidity and mortality for the patient negating the benefit of MIS. Therefore, it must be stressed that minimally invasive reoperative surgery should be performed by an experienced surgeon with a heightened concern for iatrogenic misadventures.

Avoiding Organ Injury: Adjuncts

Adhesions from previous surgery or inflammatory processes can distort tissue planes, making it difficult to identify anatomical landmarks typically used to avoid injury to critical structures. The utilization of adjunct techniques can assist with anatomical orientation and diminish the risk of injury.

Ureters

Iatrogenic ureteral injuries during colorectal surgery are associated with significant morbidity and higher mortality rate.¹²⁰ Historically, the incidence of injury was reported to be 0.24 to 1.95%¹²¹⁻¹²³; however, a recent national database study found the incidence to be rising over the past decade from 2.3 to 3.8%.¹²⁰ Reoperative pelvic surgery is associated with a higher risk for ureteral injury, although this has not been consistently demonstrated.²² Given the potential anatomical distortion anticipated from prior dissection and scarring, it can be difficult to identify the ureters as they cross the iliac bifurcation. One technique to assist with identification of the ureter is to locate it in an anatomically undisturbed area such as the splenic flexure and to trace the ureter caudally after it exits the renal pelvis. A commonly employed technique is the use of ureteral stents. Tsujinaka et al found that ureteral stents were more likely to be placed when the etiology for operation was inflammatory in

nature, including CD, diverticulitis, abscess, and fistula.¹²⁴ Lighted ureteral stents have been developed in an effort to compensate for the decrease and loss of tactile feedback when palpating ureteral stents during laparoscopy and robotic surgery, respectively. Although they were never shown to reduce the incidence of ureteral injury, reported rates of ureteral identification with lighted stents are greater than 80%.¹²⁵

Rectum

Identification of short rectal stumps during reoperative MIS Hartmann's reversal cases or completion proctectomy can be challenging due to narrow pelvis in males in particular, dense pelvic scarring that can obscure the retained rectum, and reduced or nonexistent tactile feedback during laparoscopic and robotic procedures, respectively. Adjuncts for rectal identification are varied and implement both visual and tactile cues. Suture marking of the rectal stump at the time of the index procedure and preoperative endoscopic tattoo of the proximal rectal staple line have been used to improve identification. Intraoperative proctoscopy or cannulation with a dilator or sizer can improve identification of the correct planes and assist with the abdominal dissection. Access to the presacral plane should be initiated anterior to the sacral promontory in the standard fashion. The ease of this dissection can be affected by the extent of prior rectal mobilization during the index procedure. Care should be taken during this step to avoid entering the previously transected rectal mesentery in an effort to lessen excess blood loss.

In the event that significant difficulties are encountered with plane identification or if there is major concern for pelvic organ injury, intraoperative assistance from minimally invasive urologists and/or gynecologists should be obtained to assist with safe completion of complex reoperative procedures. This is of particular importance in the event of intraoperative organ injury, when assistance should be obtained and conversion to open surgery should be strongly considered.^{126–128}

Barriers to Reoperative Minimally Invasive Colorectal Surgery

The learning curve to be considered proficient in MIS is ill-defined in the current literature. It is well accepted that outcomes are improved when procedures are performed by experienced operators in high-volume centers. But what qualifies a surgeon as experienced has been evaluated in the literature using inconsistent parameters. A recent systematic review of 34 studies addressing the learning curve for minimally invasive colorectal surgery was best determined by cumulative sum (CUSUM) methodology evaluating rates of conversion, complication, anastomotic leak, local recurrence, blood loss, operative time, and adequacy of oncologic dissection. The number of cases proposed to reach proficiency in laparoscopic surgery ranged from 5 to 310, with an average of 30 to 50; in comparison, the reported number of cases to determine robotic proficiency was 15 to 30.¹²⁹ No studies have specifically addressed the learning curve required for reoperative colorectal cases, either open or using minimally invasive techniques. Several cases series reporting on outcomes following reoperative MIS colorectal surgery

have emphasized the need for prerequisite expertise with minimally invasive laparoscopic abdominal and pelvic surgery, although no specific training or volume requirement have been proposed.

Conclusion

Reoperative abdominal and pelvic MIS can be safely performed by experienced surgeons skillful at adapting operative plan and strategy to accommodate anatomical distortion and additional challenges anticipated in the reoperative abdomen. With appropriate patient selection and preoperative planning, conversion rates of MIS reoperative colorectal surgery are comparable to non-reoperative cases with measurable short-term clinical benefits. When reoperative procedures using minimally invasive techniques are unsafe or complicated by adverse events, prompt recognition of injuries, conversion, and repair is essential.

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