

Determinants of outcomes in laparoscopic colorectal surgery

A multiple regression analysis of 416 resections

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Abstract

Background: To date, most large series of laparoscopic colorectal procedures have been descriptive reports that do not account for the potentially complex interaction of outcome predictors. The purpose of this study was to identify the preoperative factors that predict operative time, conversion to open surgery, and intraoperative and postoperative complications in laparoscopic colorectal surgery.

Methods: Multiple regression techniques were used to analyze 416 laparoscopic resections from a prospective database of laparoscopic colorectal procedures performed between April 1991 and April 1998. The preoperative factors considered were patient-specific (age, gender, weight) or disease-specific (diagnosis of cancer, Crohn's disease, diverticulitis, fistula). Surgical experience of ≤ 50 cases was also considered. Finally, all resections were represented by a combination of the following five procedure components: resections of the (a) hepatic flexure, (b) splenic flexure, (c) sigmoid, and (d) rectum, or (e) a perineal dissection.

Results: Patient weight, Crohn's disease, and each of the five individual procedure components incrementally lengthened operative time. Conversion to open surgery was influenced by the patient's weight, malignancy, and early experience of the surgeon. The risk of a postoperative complication was increased by the patient's age, resection of the perineum, and the presence of a fistula. No factors significantly influenced the risk of an intraoperative complication.

Conclusions: Several preoperative factors that significantly affect outcomes in laparoscopic colorectal resections have been identified. Consideration of these factors may help in case selection and estimation of operating time; they should also be valuable when patients are informed of their risk of conversion and complications.

Key words: Colorectal surgery — Laparoscopic colectomy — Laparoscopy — Outcomes — Regression analysis

Colorectal resections are among the most challenging current applications of laparoscopic surgery. In addition to the skill requirements needed for other advanced laparoscopic procedures, including control of multiple blood vessels and large specimen extraction, it is also necessary to operate in multiple abdominal quadrants and in many cases to restore intestinal continuity with an anastomosis. Furthermore, there is a wide variation in the presentation of cases, indications for surgery, and the extent of each planned resection.

As evidence mounts that patients who opt for laparoscopic colorectal procedures experience less discomfort and more rapid postoperative recovery [3, 11, 15], the demand on surgeons to acquire these advanced skills is increasing. An understanding of the potential hazards and their implications for operative outcome is important for surgeons who want to acquire more experience with laparoscopic colorectal resections.

In numerous descriptive case series employing simple comparative analyses, various disease-specific, patient-specific, and procedure-specific factors have been associated with longer operating times and an increased risk of complications or conversion to open surgery. However, case selection, indications for surgery, and type of procedures have varied widely in these reports. The significance of these multiple interrelated factors on operative and postoperative outcomes is difficult to understand. Many investigators have restricted their analyses to procedural or disease subsets to reduce confounding, which has the unfortunate effect of reducing the number of cases and subsequent power of these analyses.

Therefore, we designed a unique study that uses multiple linear and logistic regression techniques to analyze our

own large experience with laparoscopic colorectal surgery. Our goal was to make maximal use of our case series to identify the preoperative factors that significantly predict operative time, risk of conversion to open surgery, and rate of intraoperative and postoperative complications.

Methods

Between April 1991 and April 1998, three surgeons performed 438 consecutive, unselected laparoscopic colorectal procedures. Data on patient demographics, indications for surgery, procedure performed, operating time, conversions to open surgery, and intraoperative and postoperative complications were accumulated in a prospectively designed computer database.

All patients received preoperative intravenous antibiotics and, as appropriate, a mechanical bowel preparation. Informed consent was obtained for the planned laparoscopic procedure. In all cases, the bowel was mobilized laparoscopically; however, the techniques of division of the blood supply, specimen extraction, and fashioning the anastomosis varied.

Surgical technique

Right-side resections. For ileocecal resection and right hemicolectomy, the cecum and hepatic flexure of the colon first were mobilized laparoscopically. The right ureter was identified. Division of the blood supply, bowel resection, and either a stapled or hand-sewn anastomosis were performed extracorporeally through a small extension of the midline trocar incision.

Left-side resections. For sigmoid colectomy, left hemicolectomy, and anterior resection, bowel mobilization and division of the blood supply were performed laparoscopically. The left ureter was identified in all cases. Specimen extraction was performed through a small muscle-splitting incision in the left iliac fossa. The anvil of an appropriately sized circular stapling device was inserted in the proximal bowel segment, and the anastomosis was completed under laparoscopic visualization, with the stapler handle introduced through the rectum. For sigmoid colectomy and anterior resection, the splenic flexure was mobilized as necessary to ensure a tension-free anastomosis.

Abdominoperineal resections. For abdominoperineal resection, bowel mobilization to the level of the levator muscles and division of the blood supply were performed laparoscopically. The perineal dissection usually was performed simultaneously by a second team. Care was taken not to enter the pelvis and release the pneumoperitoneum before the laparoscopic mobilization was complete. In most cases, the bowel was resected through the perineum before being delivered back into the pelvis for stoma creation. A perineal drain was left in all cases.

Total colectomy. For total abdominal colectomy and total proctocolectomy, the bowel was mobilized to the midline laparoscopically. In general, left-sided vessels were divided laparoscopically. Right-sided vessels were taken either laparoscopically or during specimen extraction through a small extension of the umbilical trocar incision. For total abdominal colectomy, division of the bowel was performed laparoscopically, and the ileorectal anastomosis was fashioned with a circular stapling device. For total proctocolectomy, the perineal dissection usually was performed simultaneously, and in some cases, the bowel was extracted through the perineum.

Preoperative factors

Thirteen preoperative factors that might reasonably be thought to impact on surgical outcomes were selected on the basis of our own clinical experience and common findings reported in the literature. The patient-specific factors were gender, age, and weight. Disease-specific factors consisted of diag-

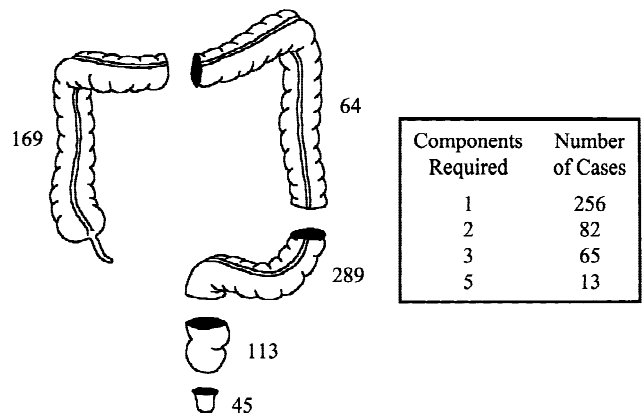


Fig. 1. Model demonstrating procedure components and the frequency of each. The inset table shows the number of resections involving multiple procedure components.

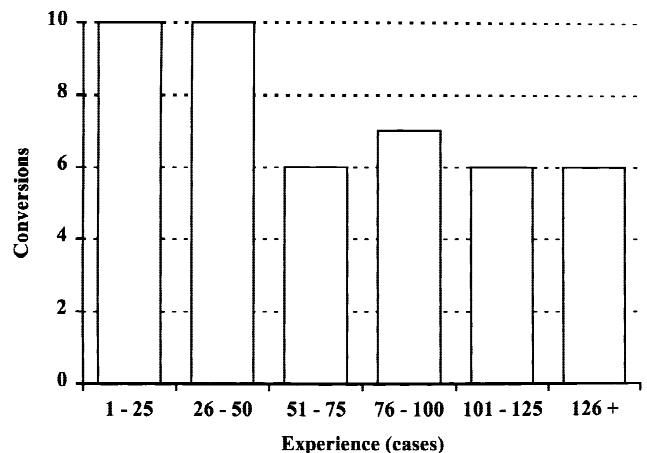


Fig. 2. Number of conversions to open surgery for each of six levels of experience with laparoscopic colorectal surgery. Although differences between groups are not statistically significant, it does appear that the relationship between experience and conversion rate is not linear.

noses of malignancy, Crohn's disease, diverticulitis, and the presence of a fistula.

The operative procedure was represented in each case as a combination of the following separate procedure components: (a) mobilization or resection of the hepatic flexure of the colon, (b) mobilization or resection of the splenic flexure of the colon, (c) resection of the sigmoid colon, (d) resection of the rectum, and (e) a perineal dissection (Fig. 1).

Initially, operative experience was denoted as each individual surgeon's case sequence number. When operative experience was divided into six even groups, it was apparent that the rate of conversion to open surgery was higher for the first 50 cases before dropping to a steady state for subsequent surgical experience (Fig. 2). Although this difference was not statistically significant, it did imply that a linear model might not be an appropriate representation (i.e., conversions did not decline steadily with experience). In this analysis, therefore, operative experience was represented by two levels. Early experience was defined as the first 50 laparoscopic colorectal procedures performed by each surgeon, whereas late experience referred to procedures done after the first 50 cases.

Definition of outcomes

Complications were defined as any unintentional event occurring during surgery or in the postoperative course that required additional steps to correct or that reasonably might have been thought to increase the risk of a poorer outcome. Complications were not grouped by severity or by presumed underlying factor (surgical vs nonsurgical). Intraoperative complications were noted during the procedure and recorded postoperatively.

Table 1. Distribution of laparoscopic colorectal procedures

Procedure	<i>n</i>
Sigmoid colectomy	131
Right hemicolectomy	123
Anterior resection	68
Total abdominal colectomy	33
Abdominoperineal resection	32
Total proctocolectomy	13
Left hemicolectomy	12
Colostomy	7
Colostomy/ileostomy closure	6
Transverse colectomy	4
Proctectomy + ileal J pouch	2
Other	7
Total	438

Postoperative complications were assessed daily in the hospital and on regular follow-up.

All procedures were attempted laparoscopically first. Any case that could not be completed laparoscopically as planned was considered a conversion to open surgery.

Operative time was measured from the first skin incision to the application of dressings. Total operating room time was not used because anesthetic preparation time varies.

Statistical analysis

Multiple linear or logistic regression analysis was performed for each outcome using all thirteen prospective variables (SAS System for Windows release 6.12; SAS Institute, Cary, NC, USA). Forward stepwise selection of significant variables was employed; a *p* value of 0.05 was considered significant.

Results

The distribution of laparoscopic colorectal procedures in this series is shown in Table 1. Segmental resections, consisting mostly of right hemicolectomies and sigmoid colectomies, constituted the majority of cases; however, a number of more extensive procedures required surgery in multiple abdominal quadrants. Of 438 procedures in the computer database, 416 laparoscopic resections could be represented accurately by a combination of the five procedure components (Fig. 1).

The 416 patients comprised 213 men and 203 women. The average age was 57.8 ± 18.5 years (range, 12–92), and the average weight was 66.7 ± 16.7 kg (range, 35.5–143.0). Surgery was performed for a diagnosis of cancer in 187 cases (45%), diverticulitis in 101 cases (24%), and Crohn's disease in 44 cases (11%). Thirteen patients (3.1%) had fistulas.

Intraoperative complications

Intraoperative complications occurred in 32 patients (7.7%). The most common complications were hemorrhage, bowel injury, and instrument failure (Table 2). The occurrence of an intraoperative complication was associated with a 25% rate of conversion to open surgery. No preoperative factors were significantly predictive of an intraoperative complication.

Table 2. Intraoperative complications

Complication	<i>n</i>	%
Hemorrhage	15	3.6
Bowel perforation	10	2.4
Stapling device failure	3	0.7
Partial ureteric transection	1	0.2
Bradycardia	1	0.2
Gallbladder serosal burn	1	0.2
Missed lesion ^a	1	0.2
Total	32	7.7

^a Specimen examined intraoperatively and additional resection performed

Conversion to open surgery

The overall rate of conversion to open surgery in this series was 11%. The most common reasons for conversion were tumor fixation or inability to perform adequate oncologic resection, and inflammation or adhesions (Table 3). On multiple logistic regression analysis, factors predictive of conversion to open surgery were patient weight, a diagnosis of malignancy, and early experience of the surgeon (Table 4).

Operative time

Average operating time in this series was 177 ± 78 min (range, 50–605). Using multiple linear regression, the factors that contributed significantly to operative time were patient weight and a diagnosis of Crohn's disease. Additionally, all five individual procedure components (mobilization or resection of the hepatic or splenic flexures, resection of the sigmoid colon or rectum, and performance of a perineal dissection) also contributed significantly and incrementally to operating time (Table 5).

Postoperative complications

Of the cases completed laparoscopically, the overall rate of postoperative complications was 29%. Small bowel obstruction or prolonged ileus was the most common postoperative complication, occurring in 8.9% of cases; four cases required repeat surgery. Other complications are summarized in Table 6. Seven deaths (1.9%) occurred; two were due to sepsis and five to cardiac events. Factors associated with a higher risk of postoperative complications on multiple logistic regression were age, the presence of a fistula, and performance of a perineal dissection (Table 7).

Discussion

These two basic principles of laparoscopic surgery cannot be overstated: (1) No compromise in surgical technique should be made to complete a procedure laparoscopically, and (2) conversion to open surgery should not be considered a complication of laparoscopic surgery. These principles are particularly relevant to the performance of laparoscopic resections for cancer.

Tumor fixation or inability to perform an adequate oncologic resection accounted for 45% of conversions to open

Table 3. Conversions to open surgery

Reason for conversion	n	%
Tumor fixation or inadequate distal clearance	20	4.6
Adhesions and inflammation	9	2.2
Hemorrhage	3	0.7
Obesity	2	0.5
Stapling device failure	2	0.5
Repair of injury	2	0.5
Other	7	1.7
Total	45	11

Table 4. Multiple logistic regression analysis of conversions to open surgery

Factor	β	p value	Odds ratio
Intercept	-5.5435	0.0001	—
Weight	0.0327	0.0024	1.39/10 kg (CI 1.12, 1.71)
Malignancy	1.0195	0.0104	2.77 (CI 1.27, 6.05)
Early experience	0.7783	0.0434	2.18 (CI 1.02, 4.63)

CI, confidence interval

Baseline predicted risk for a 70-kg patient, without malignancy, in the hands of an experienced surgeon is 3.9%

Predicted risk for a 90-kg patient, with malignancy, in a surgeon's early experience is 45%

Table 5. Multiple linear regression analysis of operating time

Factor	β	p value
Intercept	22 ± 21 min	0.289
Weight	5.9 ± 2.1 min/10 kg	0.005
Crohn's disease	28 ± 11 min	0.015
Hepatic flexure	76 ± 15 min	0.0001
Splenic flexure	38 ± 13 min	0.004
Sigmoid	86 ± 16 min	0.0001
Rectum	45 ± 10 min	0.0001
Perineum	34 ± 13 min	0.012

R² model = 0.4332

surgery in this series. Lacy et al. reported a 12.7% conversion rate in 118 cases; 67% of conversions were attributable to tumor invasion of adjacent organs [8]. In their series of 95 cases, Ramos et al. reported that obesity was one of the most common reasons for conversion. Additionally, patients operated on for malignancy comprised the greatest number of cases requiring conversion [12]. Reissman et al. and Agachan et al. found no change in conversion rate with experience [1, 14], but Senagore et al. showed that conversion rates declined between the second and third groups of 20 patients in a series of 60 cases [16]. In our analysis, patient weight, a diagnosis of cancer, and being in the surgeon's early experience (i.e., the first 50 cases) were all significant predictors of conversion to open surgery.

The overall rate of intraoperative complications in this series is comparable to that reported in other large series [2, 7, 10, 14]. None of the 13 prospective factors considered, including surgeon experience, were predictive of the occurrence of an intraoperative complication (Table 8).

Prior abdominal surgery and the presence of adhesions were not accounted for in this analysis because their impact, if any, cannot be ascertained prospectively. In itself, the

Table 6. Postoperative complications

Complication	n	%
Ileus/bowel obstruction ^a	33	8.9
Wound infection ^b	20	5.4
Urinary retention	18	4.8
Cardiac	13	3.5
Anastomotic leak	6	2.0 ^c
Delirium/confusion	6	1.6
Pulmonary	5	1.3
Hemorrhage	5	1.3
Abscess	3	0.8
Thromboembolic	3	0.8
Other	14	3.8
Death	7	1.9
Total	108 ^d	29

^a Reoperation required in four cases (12%)

^b 4.0%, excluding perineal wound infections

^c Denominator is 306, counting only anastomoses

^d Some patients had multiple complications

Table 7. Multiple logistic regression analysis of postoperative complications

Factor	β	p value	Odds ratio
Intercept	-3.7015	0.0001	—
Age	0.04	0.0001	1.49/10 yr (CI 1.27, 1.75)
Fistula	1.8461	0.0079	6.34 (CI 1.62, 24.7)
Perineum	1.7734	0.0001	5.89 (CI 2.75, 12.6)

CI, confidence interval

Baseline predicted risk for a 50-year-old patient, without a fistula, not requiring a perineal dissection, is 18%

Predicted risk for a 70-year-old patient, with a fistula, requiring a perineal dissection, is 95%

existence of an abdominal incision has no implication for the feasibility of a planned laparoscopic procedure. Although it may portend the presence of adhesions, this factor and the severity of the adhesions still cannot be determined until after the start of the procedure. If they are dense enough and inconveniently located, adhesions may ultimately lead to conversion to open surgery in rare cases; however, in other cases, they may be lysed with minimal or no lengthening of operating time. In at least three case series, adhesions and prior abdominal surgery had no consistent impact on operative time or rate of conversion to open surgery [1, 16, 18].

Although body mass index might have been a better indicator of obesity in this study, data on patient height was not available in all cases. Nonetheless, patient weight was still a significant predictor of both the risk of conversion to open surgery and operating time. An odds ratio of 1.4 per 10 kg of patient weight suggests that a patient weighing 90 kg, for example, would be expected to have roughly twice the odds of being converted to open surgery as a patient weighing 70 kg. This relationship is valid only over the observed range of weights in this study (35.5–143 kg). This finding is easy to understand, considering the impact of a thick, heavy abdominal wall and fatty omentum and mesentery on access and visualization in a restricted abdominal compartment.

None of the five individual procedure components studied by us was a significant predictor of intraoperative complications or conversion to open surgery. Operative time,

Table 8. Summary of predictors of surgical outcomes

	Intraoperative complications	Conversion to open surgery	Operative time	Postoperative complications
Patient-related				
Age	—	—	—	Yes
Weight	—	Yes	Yes	—
Sex	—	—	—	—
Disease-related				
Malignancy	—	Yes	—	—
Crohn's disease	—	—	Yes	—
Diverticulitis	—	—	—	—
Fistula	—	—	—	Yes
Procedure-related				
Hepatic flexure	—	—	Yes	—
Splenic flexure	—	—	Yes	—
Sigmoid	—	—	Yes	—
Rectum	—	—	Yes	—
Perineum	—	—	Yes	Yes
Early experience	—	Yes	—	—

however, was increased significantly and incrementally by the addition of each individual procedure component. That more extensive procedures require longer operating time is intuitive and also serves as the basis for our concern about studies that draw conclusions from the average of a wide range of operating times for a broad selection of procedures. One of the strengths of this study is the use of the procedure component model. Dividing each procedure into separate components allows all resections, regardless of complexity, to be compared. In this way, the impact of patient-specific factors, disease-specific factors, and experience can be compared between cases, while the multiple regression model corrects for the differing extent of surgery.

Several authors have attempted to define the learning curve for laparoscopic colorectal surgery in terms of operative time. Learning curves ranging from 11 to 70 cases have been reported, based on a stable reduction in operating time [1, 16, 17, 18]. In this series, when other prospective factors were controlled for using multiple regression analysis, experience was not a significant factor in predicting operative time. The lack of any decline in operative time with experience in this study may be due, at least in part, to the fact that the three surgeons were already experienced in a variety of other basic and advanced laparoscopic procedures.

Where specific rates of postoperative complications have been reported in large series, they have ranged from 6.8 to 22% [1, 8, 14]. Some would argue that an ileus that resolves without requiring further surgery should not be counted as a postoperative complication. Such cases constituted 31% of the postoperative complications in this series. In addition, 8.3% of complications (50% of urinary complications) were postoperative urinary retention occurring in patients who underwent perineal dissections. This same group of patients accounted for 25% of the wound infections that occurred in the perineal incision, not at trocar sites. One of the proposed benefits of laparoscopic colorectal surgery is a reduction in the rate of wound infections [4, 7, 8, 14]. In this series, the rate of wound infections was 5.4% overall and 4% when perineal wound infections are excluded.

The age of the patient was a significant prospective factor in predicting the risk of a postoperative complication.

In fact, 70% of postoperative complications occurred in patients aged ≥ 60 years. One reason for this difference may be that cardiac complications accounted for 16% of postoperative complications in patients aged ≥ 60 years, as compared with 3.2% of complications in the younger group. Furthermore, all seven deaths occurred in the older group. Information on comorbid conditions was not available on all patients in this series, and it can be expected that the older patients in this series would have a higher degree of coexisting illness that impacted on postoperative complications. These findings are contrary to those of Reissman et al., who observed no difference in complications between similarly aged patient groups [13]. However, their series involved only 72 matched patients with an overall complication rate of 12.5%.

Thirteen patients in our series had fistulas. Opinions differ widely as to whether fistulas associated with either Crohn's disease or diverticulitis should be managed laparoscopically [5, 9, 11, 19]. Although six postoperative complications occurred in patients with fistulas, half of them could not be considered related to the presence of a fistula (angina, confusion, atelectasis). Despite the statistically higher rise of postoperative complications, the presence of a fistula was not a significant predictor of operative time, intraoperative complications, or conversion to open surgery. We believe that a fistula can be managed laparoscopically and that the presence of a fistula should not be a contraindication to laparoscopic colorectal resection.

Most of the findings of this analysis are not surprising. It seems a matter of common sense that procedures on obese patients or patients with malignancy are more challenging. However, an important part of this study is also what we did not find. Although operating time may be longer, laparoscopic resections for Crohn's disease were not associated with an increased risk of complications or conversion to open surgery in keeping with other studies [19]. Furthermore, laparoscopic resections for diverticulitis were safe and feasible, as has also been reported by others [5], and were not associated with either increased operating time or increased risk of conversion or complications. Finally, mobilizing the splenic flexure, which is often considered the most technically challenging procedure component [6], was

associated only with increased operating time and no increased risk of complications or conversion.

Conclusions

Although no preoperative factor was identified as a predictor of intraoperative complications, 11 factors were found to be significant in predicting three operative outcomes. Patient weight, a diagnosis of malignancy, and surgeon experience were predictors of the risk of conversion to open surgery. Patient weight, a diagnosis of Crohn's disease, and each of five possible individual procedure components of a planned resection contributed significantly to operative time. Finally, patient age, the presence of a fistula, and performance of a perineal dissection impacted on the development of postoperative complications.

It is not intended, as a result of this analysis, that any of these factors be considered a contraindication to laparoscopic surgery. Rather, these findings should be helpful in case selection and projecting operative time and for informing patients preoperatively of increased risks for conversion to open surgery and postoperative complications.

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