Laparoscopic Colectomy: Does the Learning Curve Extend Beyond Colorectal Surgery Fellowship?

Joshua A. Waters, MD, Ray Chihara, MD, Jose Moreno, MD, Bruce W. Robb, MD, Eric A. Wiebke, MD, Virgilio V. George, MD

ABSTRACT

Background and Objectives: As minimally invasive colon and rectal resection has become increasingly prevalent over the past decade, the role that fellowship training plays has become an important question. This analysis examines the learning curve of one fellowship-trained colorectal surgeon in his first 100 cases.

Methods: This was a prospectively collected retrospective analysis of the first 100 laparoscopic colon and rectal resections performed between July 2007 and July 2008 by a colorectal (CRS) fellowship trained surgeon at a Veteran’s Administration (VA) and county hospital. Included were all emergent and nonemergent laparoscopic cases.

Results: Mean age was 63 (range, 36 to 91). The 100 resections included 42 right, 6 left, 32 sigmoid, 13 rectal, and 7 total abdominal colectomies. Indications were 55% cancer, 20% unresectable polyp, 18% diverticular, 4% inflammatory, and 3% other. Overall mortality was 3%. Overall morbidity including wound infection was 24%. Early and late groups were similar in age, ASA score, and indication. Conversion rate was 4%. No statistical difference was seen in mortality, morbidity, EBL, LOS, margin, lymph nodes, or conversions between the first and second 50 cases (P < 0.05). Right and sigmoid colectomy operative time decreased by 40.0% and 19.6%, respectively.

Conclusion: Prior investigators have demonstrated a significant learning curve for laparoscopic colorectal surgery. In the first 100 cases, there is no difference in mortality or morbidity between early and late cases. Alternatively, operative times decreased with experience. Laparoscopic training during CRS fellowship surpasses the learning curve in regard to safety and outcome, whereas operative efficiency improves over the first year of practice.

Key Words: Laparoscopy, Colectomy, Learning curve, Colon cancer.

INTRODUCTION

Since the advent of laparoscopic general surgery in 1985, minimally invasive surgery has changed the face of surgical practice. In few areas of surgical practice is this more apparent than in the current practice of colorectal surgery. Laparoscopic colon resection was initially described by both Jacobs et al and Fowler et al in 1991. As is commonplace in surgical innovation, there was initial skepticism and reluctance with regard to the role of laparoscopy as it related to large bowel resection. This was especially fervent with regard to colon resection for malignant indications. The initial experience as described by a number of early investigators, highlighted port-site recurrences and locoregional recurrence rates that underlined the concerns regarding this approach. Subsequently, large prospective trials have allayed these initial concerns, especially with regard to the oncologic validity of this approach.

The benefits of a minimally invasive approach in colorectal resection have been intensely studied. Prior investigators have demonstrated improved short-term factors including decreased length of stay, earlier return of bowel function, reduced postoperative pain, and improved short-term quality of life. Long-term improvements in wound complications and decrease in subsequent enteroadhesive bowel obstruction have also been suggested.

Because the efficacy and benefits of this approach have been established, these techniques have become an integral part of colorectal practice. One of the prevailing issues highlighted in these large trials was the reproducibility of these results in real surgical practice. As an increasing number of colorectal surgeons begin to use these approaches on a regular basis, the question arises as to whether the learning curve is adequately reached during the fellowship training period. Recently, investigators demonstrated that laparoscopic colon resection could be performed safely under the supervision and structure of a
colorectal fellowship with increasing independence after the first 50 cases. The learning curve has also been investigated as it relates to different institutional settings. In addition, other investigators have demonstrated the learning curve as it relates to intraoperative factors, such as right- versus left-sided resections.

Our hypothesis is that the intense laparoscopic experience gained during current colorectal surgery fellowship training meets the learning curve for laparoscopic colon and rectal resection with regard to safety and efficacy. To assess this, we examined the entire operative experience accrued during the first year of independent surgical practice of a single colorectal surgeon and compared the early and late post fellowship experience.

**MATERIALS AND METHODS**

**Assurances**

These studies were conducted in strict compliance with the Indiana University School of Medicine Institutional Review Board.

**Patient Population and Study Criteria**

This is a retrospective study of the first 100 patients undergoing laparoscopic colon and rectal resections by a single attending surgeon (VG) following a dedicated colorectal surgery fellowship. All of these procedures were performed between July 2007 and July 2008. The cases took place at either a high-volume county hospital or Veterans Administration Hospital in Indianapolis, Indiana. All cases that were initiated as pure laparoscopic, laparoscopic-assisted, hand-assisted laparoscopic, or laparoscopic approach with ultimate conversion to open were included in this analysis. Dissection and ligation of named vessels was undertaken in a totally intracorporeal fashion, whereas gastrointestinal anastomosis was performed almost exclusively in an extracorporeal manner. Cases were included regardless of indication. Data were collected in a prospectively maintained database that was further supplemented by retrospective chart review. No patient was included multiple times in this analysis in the setting of reoperation. This laparoscopic experience represented 96% (100 of 106) of colectomies performed in this time period by the author (VG).

**Parameters Assessed**

For the purposes of analysis and comparison, cases were divided into early and late groups. The first 50 cases comprised the early group, while the second 50 cases were defined as the late group. Patient factors and demographics were assessed including age, sex, American Society of Anesthesiology Classification (ASA), emergent or nonemergent case. Operative indications were also assessed; these were divided into operations for cancer, polyp/adenoma, inflammatory bowel disease, diverticular disease, and other indications. Intraoperative factors were also compared, including estimated blood loss (EBL), operative time, and conversion rate. Oncologic adequacy was assessed in cases performed for malignancy, utilizing the overall number of lymph nodes, and proportion of positive margins. The margin was counted as positive whether in the radial, proximal, or distal margin. Finally, postoperative characteristics were compiled that included length of stay (LOS), postoperative morbidity, and 30-day overall mortality. Morbidity was defined as any postoperative complication including wound infection.

**Data Analysis**

The data collected regarding the above criteria were compiled and compared with regard to the type of operation and whether they occurred in early or late groups. Continuous variables (EBL, operative time, age, and other such things) were used to derive a mean value in each group. These were tested for statistical significance using the Student’s t test, with an accepted P value of <0.05 as significant. Proportions were evaluated using Fisher’s exact test. An assessment of the trend in operative times was evaluated using linear regression analysis. This yielded a best-fit line and the resulting r-squared value and slope.

**RESULTS**

In all, 100 colon resections were performed in the first year of practice (July 2007 to July 2008) by a single fellowship trained colorectal surgeon (VG). These 100 resections included 42 right, 38 left/sigmoid, 13 rectal (including low anterior or abdominoperineal resections), and 7 total abdominal colectomies.

Patient demographics included a mean age of 63 years (range, 36 to 91). The average overall ASA classification was 2.8 (range, 1 to 3), 52% of patients were male. There were no emergent cases in the early group and 3 (6%) emergent cases in the late group. Operative indications included 55% cancer, 20% polyp or adenoma, 18% diverticular bleeding or diverticulitis, 4% inflammatory bowel disease, and 3% other. There was no significant difference in the indications for operations between the early and late cases as seen in Table 1.
There was no significant difference in estimated blood loss overall between the early (158.9mL) and late (123.1mL) cases (P = 0.11). In addition, there was no significant difference in blood loss in any of the operative subgroups as illustrated in Table 2. A large difference in mean blood loss was seen in the total colectomy group, but the small number of cases in these groups did not allow for the demonstration of statistical significance (Figure 1). Operative times differed in the early and late groups. The mean overall operative time was 3 hours and 34 minutes and 2 hours and 40 minutes in the early and late groups, respectively (P = 0.001) (Figure 2). Statistically significant reductions in mean operative time of 71 minutes (40.0%) and 43 minutes (19.6%) were seen in both right (P = 0.003) and sigmoid (P = 0.018) colectomy groups, respectively, between the early and late cases. Each case was examined sequentially with regard to operative time in the right hemicolectomy and sigmoid colectomy groups. Based on linear regression, these demonstrated a slope of -0.002 and an r value of 0.27, (Figure 3a) and a slope of -0.0001 and an r value of 0.12 (Figure 3b) for right and sigmoid colectomies, respectively. There were 2 conversions in each group for a total conversion rate of 4%.

Regarding oncologic resections, there was an overall positive margin rate of 4% and 8% in the early and late groups.

### Table 1.
Demographic Factors of Early and Late Operative Groups

|                      | Overall | First 50 Cases | Second 50 Cases |
|----------------------|---------|----------------|-----------------|
| Age (yrs)            | 63      | 62.2           | 62.6            |
| Male gender          | 52%     | 48%            | 56%             |
| ASA                  | 2.8     | 2.8            | 2.8             |
| Emergent (%) Indication | 3%    | 0%             | 6%              |
| Cancer               | 55%     | 50%            | 60%             |
| Polyp/adenoma        | 20%     | 28%            | 12%             |
| Diverticular         | 18%     | 16%            | 20%             |
| Inflammatory         | 4%      | 4%             | 4%              |
| Other                | 3%      | 2%             | 4%              |

### Table 2.
Comparison of Surgical Outcomes in Early and Late Operative Groups

|                                      | First 50 Cases | Second 50 Cases | P Value* |
|--------------------------------------|----------------|-----------------|----------|
| Estimated Blood Loss (mL)            |                |                 |          |
| All operations                       | 158.90         | 123.10          | 0.110    |
| Right colectomy                      | 103.89         | 72.29           | 0.170    |
| Left/sigmoid colectomy               | 171.25         | 117.78          | 0.101    |
| Low anterior or abdominoperineal resections | 178.57       | 210.00          | 0.920    |
| Total abdominal colectomy            | 280.00         | 75.00           | 0.089    |
| Total Nodes Resected                 |                |                 |          |
| All                                  | 16.8           | 15.7            | 0.567    |
| Right colectomy                      | 16.3           | 15.9            | 0.394    |
| Left/Sigmoid colectomy               | 16.4           | 14.7            | 0.380    |
| Positive Margins Operative Time (hr:min) |            |                 |          |
| All operations                       | 3:34           | 2:40            | NS       |
| Right colectomy                      | 2:54           | 1:43            | 0.001*   |
| Left/Sigmoid colectomy               | 3:39           | 2:56            | 0.018*   |
| Low anterior or abdominoperineal resections | 5:25       | 3:40            | 0.055    |
| Total abdominal colectomy            | 4:09           | 4:22            | 0.659    |
| Conversion rate                      | 4.0%           | 4.0%            | n/a      |
| Morbidity                            | 24.0%          | 24.0%           | n/a      |
| 30 Day Mortality                     | 4.0%           | 2.0%            | 0.532    |

*Statistical significance defined as P < 0.05.
There was only one distal margin positive in the late group. This occurred in a 92-year-old undergoing a sigmoid colectomy. Initial margin was interpreted as negative and then subsequently positive on final pathology. All other positive margins were positive in the radial plane. Total number of lymph nodes was 16.8 and 15.7 in early and late cases (\(P=0.67\)). There was no statistically significant difference in lymph node survey in any operative subgroup (Figure 4).

Overall mortality was 3%, with no significant difference seen between the early and late experience (\(P=0.53\)). The overall morbidity including wound infection was the same between the 2 groups at 24% overall. Overall, 8 wound infections required intervention, 5 patients with anastomotic leak or abscess requiring percutaneous drainage, 2 reoperations (1 for peritonitis and 1 for fascial

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**Figure 1.** Estimated blood loss (EBL), as classified by operative type in both early and late case groups, demonstrates no statistically significant change between early and late groups.

**Figure 2.** Operative duration compared between early and late operative groups, subdivided by operative type demonstrates reduced operative times (\(P<0.05\)).

**Figure 3.** Operative time learning curve for right-sided colon resection (A) and sigmoid colon resection (B) as a function of accrued case experience show decreased operative time. These curves are fitted with a linear regression analysis.

**Figure 4.** Lymph node survey shows no significant difference in early and late oncologic resections.
dehiscence), 1 ureteral injury, 8 medical complications (MI, acute renal failure, or pneumonia).

There was no statistically significant difference in length of stay between early and late groups, 8 days (early) versus 9 days (late) (P=0.56). No subgroup demonstrated a statistical difference in LOS. Shortest length of stay was seen in the right colectomy group with an average of 6 days. The mean LOS for total colectomy was the longest at 16 days (Figure 5).

DISCUSSION

As the paradigm in colorectal and general surgery has shifted over the past decade toward increasing the role of minimally invasive approaches for hindgut surgery, a consistent focus has been placed on the “learning curve” associated with these techniques. As these procedures have become a more significant part of residency and fellowship training, attention has turned to what role specialized fellowship training has in meeting these training demands for the colorectal surgeon. We hypothesized that the laparoscopically trained colorectal fellow was adequately prepared to perform safe and efficacious laparoscopic colon resection during the first year of independent practice.

In this series, we have examined the first year of colon and rectal resections of a colorectal surgeon. We assessed characteristics over the first 100 cases and used these parameters to evaluate the operations with respect to safety, efficiency, and short-term outcomes. Overall, the early and late experience involved a similar distribution of case type and operative indication. Approximately half the patients in either group underwent a resection for colon or rectal malignancy. The distribution of indications for resection seen in this series appropriately imitates the caseload faced by a practicing colorectal surgeon at a high-volume center. In the early and late experience, the groups were similar with respect to patient factors and comorbidities, allowing for appropriate comparison. As a measure of intraoperative safety, we examined blood loss and conversion rate. There was no significant difference demonstrated between the early and late operative experience. This parity in intraoperative factors is one element that we find demonstrates adequate preparation from a safety standpoint following colorectal fellowship training.

The next element of safety is the postoperative morbidity and mortality. With regard to all measures of morbidity, including superficial infections, there were no significant increases in risk to the patient from the early to late experience. Of note, there was one ureteral injury that occurred in the early experience, but this was not demonstrated to be statistically significant with regard to experience. In addition, overall 30-day mortality was statistically similar between the 2 groups. Additionally, LOS is an early surrogate for postoperative outcome that is frequently espoused as one of the benefits of laparoscopic surgery. Notably in this series, there was no significant difference with regard to postoperative stay in either the early or late operative experience. The mean LOS demonstrated in either group is somewhat longer than that of other published laparoscopic colorectal series. A number of the other series report cases that were more selective with regard to patients considered for laparoscopy, whereas this series includes the entirety of the first year experience at a county and Veteran’s Administration hospital.

Next, we measured the efficacy of colorectal resection for malignancy. An adequate lymph node survey, for operative staging, has been determined to be 12. Although there is some variability in the absolute number of lymph nodes that are counted by an individual pathologist, as long as the cases are exceeding the minimum required number of nodes for adequate staging, this should act as a measure of oncologic adequacy. With regard to both right- and left-sided resections, there were greater than an average of 15 lymph nodes obtained in both early and late experiences. There was no significant deviation in this throughout the first year of operative experience. In addition, the proportion of margin positivity (radial and/or linear) was similar in both groups. Although the rate of positive margins was somewhat elevated, this was largely due to patients in which a negative radial margin could not be achieved due to locally advanced tumors. Although both
of these parameters support the appropriateness of oncologic resection, the ultimate measure would be to demonstrate similar long-term overall and recurrence-free survival. Further investigation is warranted to explore this metric.

The final parameter that we examined was operative efficiency. All of the above findings supported the conclusion that colorectal training with a focus on laparoscopic and minimally invasive approaches has adequately prepared the surgeon to perform both safe and efficacious colon resections. Prior investigators have presented data that operative time alone is not an appropriate surrogate for the learning curve. Rather, we find that it is a measure of operative efficiency and overall comfort with these technically demanding procedures. These data have demonstrated an obvious reduction in the overall time required to perform a laparoscopic colon resection that occurs with experience over the first 100 cases. A 71-minute reduction in the operative time for a right-sided laparoscopic resection may have consequences from both a clinical and cost standpoint. The left-sided resections did show a statistically significant reduction in time, although this was not as dramatic as in the right-sided resections. In addition, the variability in times seen in the sigmoid group was much greater. This is likely due to the increased variability in indication for resection. The left-sided resections more commonly involved diverticular disease, which could explain increased operative times. Of note, extracorporeal anastomosis was utilized throughout the series. This differs slightly from the experience of some CRS-trained surgeons using intracorporeal anastomosis as initially described by Franklin et al.22

Additionally, not all reductions in operating time can be attributed to surgeon factors alone. As is common in laparoscopic surgery, a significant amount of time may be spent on nonoperative tasks (equipment acquisition, malfunction, and others). As the surgical team becomes more comfortable, this clearly has some effect in reducing the operative time. The operative times considered in this analysis were from incision to closure and did not include setup times, which could have made the improvements in efficiency potentially more dramatic.

All of these results taken together support the quality of colorectal surgery fellowship in adequately preparing the surgeon to approach the broad array of pathology and patient factors that comprise the practice of laparoscopic colon and rectal surgery. The colorectal surgeon in this case demonstrates consistency with regard to operative safety and oncologic factors in early cases and maintains this with continued experience. Those patients near the beginning of the independent operative experience appear to face no additional risk or hazard with regard to morbidity or mortality. The only area that appears to continue to improve as experience accrues is intraoperative efficiency and pace.

This analysis is limited in several significant areas. It is a retrospective analysis of data that was maintained and collected in a prospective fashion with the inherent risk of bias that this introduces. This type of analysis would not lend itself to further analysis in a prospective fashion. Secondly, due to the short-term collection of data the study does not assess the long-term outcomes of these patients. This is tempered by the similarity of perioperative outcomes as well as oncologic factors. Additionally, the laparoscopic training of this particular colorectal surgeon may not be generalizable to all colorectal surgeons. Finally, the division of cases into early and late groups was created at an arbitrary point to allow for analysis, though this includes all cases performed during the first year of experience.

**CONCLUSION**

In examining the first 100 cases of a fellowship-trained colorectal surgeon, we find that there is no difference in mortality, morbidity, blood loss, node survey, or length of stay between early and late cases following colorectal fellowship. Alternatively, operative times decrease significantly over the first 100 cases. These data support the conclusion that laparoscopic experience during colorectal fellowship adequately surpasses the learning curve in regard to safety and outcome, whereas the surgeon continues to increase operative efficiency over the first year of practice.

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