Early Learning Effect of Residents for Laparoscopic Sigmoid Resection

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OBJECTIVE: To evaluate the effect of learning the laparoscopic sigmoid resection procedure on resident surgeons; establish a minimum number of cases before a resident surgeon could be expected to achieve proficiency with the procedure; and examine if an analysis could be used to measure and support the clinical evaluation of the surgeon’s competence with the procedure.

DESIGN: Retrospective analysis of data which was prospective entered in the database.

PARTICIPANTS: From 2003 to 2007 all patients who underwent a laparoscopic sigmoid resection carried out by senior residents, who completed the procedure as the primary surgeon proctored by an experienced surgeon, were included in the study. A cumulative sum control chart (CUSUM) analysis was used evaluate performance. The procedure was defined as a failure if major intraoperative complications occurred such as intra abdominal organ injury, bleeding, or anastomotic leakage; if an inadequate number of lymph nodes (<12 nodes) were removed; or if conversion to an open surgical procedure was required.

RESULTS: Thirteen residents performed 169 laparoscopic sigmoid resections in the period evaluated. A significant majority of the resident surgeons were able to consistently perform the procedure without failure after 11 cases and determined to be competent. One resident was not determined to be competent and the CUSUM score supported these findings.

CONCLUSIONS: We concluded that at least 11 cases are required for most residents to obtain necessary competence with the laparoscopic sigmoid resection procedure. Evaluation with the CUSUM analysis can be used to measure and support the clinical evaluation of the resident surgeon’s competence with the procedure. (J Surg 70:200-205. © 2013 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: resident, teaching, laparoscopy, colorectal, learning

COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning and Improvement, Professionalism, Systems-Based Practice

INTRODUCTION

Laparoscopic colorectal surgery has grown in popularity since it was first described in 1991. Generally accepted advantages of laparoscopy include reduced blood loss, fewer adhesions, less pain, decreased risk of long-term incisional hernia formation, shorter hospital stay, better cosmesis, and a faster return to normal activities. Specific advantages of laparoscopic colorectal surgery as compared with conventional surgery include shorter duration of postoperative ileus, better pulmonary function, and improved quality of life.

Because of these advantages the number of laparoscopic colorectal procedures is increasing and a higher demand for properly trained laparoscopic surgeons has been noted. Considerable research has been focused on the learning curve for laparoscopic colorectal surgery. However, most of this research has been conducted for experienced colorectal surgeons; a learning curve in the range of 20-60 cases has been described as adequate for laparoscopic colorectal surgery.

In the current curricula, most surgical residents in the United States of America and The Netherlands do not
meet these numbers during their residency; as a consequence, recent graduates are seeking minimally invasive surgery fellowships to compensate for this deficit.\textsuperscript{12,13} On the other hand, little is known about the laparoscopic colorectal learning curve for residents in general surgery.

Today’s residents are trained in the laparoscopic era and have considerable exposure to laparoscopic procedures (e.g., appendectomy and cholecystectomy). They also usually have extensive camera-holding experience, which meant that they have spent time watching advanced laparoscopic procedures to gain familiarity with the equipment and the maneuvers.

Therefore, it could be hypothesized that the learning curve of today’s residents for laparoscopic colorectal surgery is at least as good or steep as compared with the learning curve for experienced surgeons.

We evaluated the outcome of laparoscopic sigmoid resections only of those in which the resident completed the case as the first operator. Using the data from the Leeuwarden Institute for Minimally Invasive Surgery, we evaluated if an early learning effect could be derived.

**METHODS**

From 2003 to 2007 all patients who underwent a laparoscopic sigmoid resection carried out by senior residents, who had completed the procedure as the primary surgeon proctored by an experienced surgeon, were included in the study. No preoperative selection was made. The procedures were performed in a large teaching hospital with tertiary referral for laparoscopic colorectal procedures. The supervising surgeons had performed at least 100 laparoscopic colectomies by the start of the study.

Patient demographics, operative times, blood loss, conversion rates, complications, reinterventions, and length of stay were recorded and entered in a database according to the prospective protocol. All patients were familiar with the fact that they were operated in a teaching hospital.

Before the first laparoscopic colectomy, a resident should have performed at least 50 basic laparoscopic procedures. Basic laparoscopic procedures were defined as laparoscopic cholecystectomies, laparoscopic ventral hernia repairs, and laparoscopic appendectomies. Also, the resident was required to have camera holding experience with at least 10 laparoscopic colorectal procedures.

All procedures, both for benign and malignant indications, were included because both types are suitable as a training operation.\textsuperscript{14} The surgery was performed in the standard straight laparoscopic medial to lateral approach with a low tie of the mesenteric artery.\textsuperscript{15} We always apply ligation of circulation at the level of the superior rectal artery (low tie) just caudal of the left colic artery since this is anatomically less invasive with respect to circulation and preserves the autonomous nerves at the root of the inferior mesenteric artery that might be at risk when using a high tie. Oncologically there is no difference in low or high tie resections.\textsuperscript{16}

**MOVING AVERAGE AND CUMULATIVE SUM CONTROL CHART (CUSUM) ANALYSIS**

The moving average method was used to assess changes in the operation time and to build a learning curve for each resident. Creating an average of values that “moves” with the addition of new data results in a “smoothing” of the changes of the value being analyzed. That is, by calculating the average value of an underlying indicator fluctuations are reduced. A moving average of order 15 was plotted.

In this study the CUSUM (Sn) was defined as \( Sn = P (X_i - X_o) \), where \( X_i \) was an individual attempt and \( X_o \) was the predetermined acceptable failure rate for the procedure, with \( X_i \) assigned a score of 0 for a success and 1 for a failure. The acceptable failure rate was defined such that when the target success rate was set at 85%, the acceptable failure rate was 15% or 0.15. After each attempt, the score was sequentially added to the cumulative score and plotted graphically. A positive slope of the curve indicated that the acceptable failure rate was exceeded, whereas a negative slope indicated that the failure rate was less than that considered acceptable. A failure was defined as the occurrence of major perioperative complications such as intra-abdominal organ injury, bleeding (blood loss > 250 ml), or anastomotic leakage; failure to harvest an adequate number of lymph nodes (< 12 nodes) or conversion to open surgery due to technical problems or disease severity. We like to mention that conversion should not be interpreted as a complication. In our experience preemptive conversion usually avoids complications.

In this study, CUSUM analysis was calculated for a targeted success rate of 85%, and these results were plotted against the number of cases to produce CUSUM graphs. Curve analysis involved identification of the turning point at which the graph adopted a generally downward slope. This point corresponded to the case number after which the target success rate began to be observed. The point at which the curve began to decrease from its maximum represented the end of what is considered the initial learning process.

**RESULTS**

A total of 169 sigmoid resections were completed by 13 residents. Of these cases, 64 (37.9%) were performed for curable cancer and 105 (62.1%) were elective resections for diverticular disease. The patient characteristics are shown in Table 1.

All the residents had extensive laparoscopic experience (median 253 for less complex procedures) and had performed a median of 34 laparoscopic colorectal resections (Table 2).
The surgical data are listed in Tables 3-5.

Only one major peroperative complication occurred when in one patient the left ureter was transected. This was recognized during the laparoscopic phase and laparoscopically re-anastomosed by the supervisor. The resident completed the operation. Recovery was uneventful.

Twenty of the 169 cases were converted to open surgery due to: adhesions \(n = 9\), advanced disease \(n = 4\), no visualization of critical structures \(n = 6\), and inadequate margins for resection \(n = 1\).

An anastomotic leakage occurred in 12 (7%) patients. All these patients were reoperated and a stoma created.

Three patients died (mortality 1.8%). One of them died on the first day after surgery due to a myocardial infarction. Another died following a stroke 10 days after surgery, and the third patient died due to anastomotic dehiscence, leading to abdominal sepsis and multi-organ failure.

The moving average learning curves are shown in Figures 1-4. The operation time does not seem to decline in time but there is a decline in blood loss.

The CUSUM was calculated for a success rate of 85% and the graphic analysis for all residents is shown in Figure 5. For most residents there seem to be some form of steady state of the curve after 11 cases, indicating that the target success rate had been met. Interestingly, there is one resident (number 5) whose slope stays positive and therefore does not meet the target success rate despite performing 19 laparoscopic recto sigmoid resections. This resident failed because of major peroperative complications: injury of the left ureter \(n = 1\), postoperative complications: anastomotic leakage \(n = 4\), intra-abdominal abscess \(n = 1\) and less than 12 lymph nodes in cancer patients \(n = 7\).

DISCUSSION

This study shows that an early learning effect for performing laparoscopic sigmoid resections can be observed for residents under supervision with operative results comparable to large multicenter trials for residents under supervision.7,8 Furthermore, not every resident seems to have the ability to develop adequate laparoscopic skills. In this study a learning effect could be seen in the early phase of training. This has not yet been described by others.10 The reasons

<table>
<thead>
<tr>
<th>Trainee</th>
<th>Laparoscopic Sigmoid Resections</th>
<th>Total Laparoscopic Colon Resections</th>
<th>Total Colon Resections (Open And Laparoscopic)</th>
<th>Total Laparoscopic Procedures</th>
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<tr>
<td>1</td>
<td>13</td>
<td>50</td>
<td>104</td>
<td>217</td>
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<td>18</td>
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<td>12</td>
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<td>100</td>
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<tr>
<td>13</td>
<td>9</td>
<td>36</td>
<td>120</td>
<td>399</td>
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<tr>
<td>Median</td>
<td>11</td>
<td>34</td>
<td>100</td>
<td>253</td>
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for this difference have not yet been investigated and can only be speculated upon. One explanation could be that all procedures in this study were performed under strict supervision. The strict supervision is probably also the reason that the operation time did not drop as the resident gained more experience. Other studies have also shown no drop in operating time.

Today’s residents are also trained, starting on their first day in a laparoscopic environment leading to a familiarity and confidence with laparoscopic surgery. A positive effect between computer games and laparoscopic skills has been described, and because today’s residents are from the ‘Nintendo generation’ this might be an explanation.

In this study we focused only on the learning curve for sigmoid resections, because this is one of the most frequently performed resections and is also a suitable operation with which to start training because of standard and consistent landmarks. One can argue that the number of sigmoid resections performed by our residents is limited. They perform, as shown in Table 3, a median of 11 laparoscopic sigmoid resections and a total of 34 laparoscopic colon resections during their residency. When comparing these numbers with the numbers mentioned by Tekkis et al., our numbers seem quite low. However, it is interesting to notice that our numbers are similar to American colon and rectal residents who graduate with at least 30 cases (for all types of colectomies). Based on these numbers, one could conclude that the average colon and rectal resident graduates with appropriate experience in laparoscopic colectomy.

In the new Dutch surgical curriculum, which started on 1 January 2011, a differentiation phase of 2 years (5th and 6th year) has been incorporated, probably leading to an increased exposure to advanced laparoscopic procedures.

### TABLE 5. Postoperative Complications

<table>
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<tr>
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<th>n = 169</th>
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<tr>
<td>Total patients with postoperative complications*</td>
<td>37 (21.9%)</td>
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<tr>
<td>Cardiovascular</td>
<td>1 (0.6%)</td>
</tr>
<tr>
<td>Respiratory</td>
<td>5 (3.0%)</td>
</tr>
<tr>
<td>Anastomotic leakage</td>
<td>12 (7.1%)</td>
</tr>
<tr>
<td>Other</td>
<td>30 (17.8%)</td>
</tr>
<tr>
<td>Surgical reintervention</td>
<td>12 (7.1%)</td>
</tr>
<tr>
<td>Mortality</td>
<td>3 (1.8%)</td>
</tr>
</tbody>
</table>

Data presented as counts with percentage in brackets.

* Some patients had several complications.
including colorectal surgery\textsuperscript{21} as compared with the former 1 year differentiation program.

Not everybody has the same ability to develop advanced laparoscopic skills. In our data one resident seemed to have difficulties in learning to perform a laparoscopic sigmoid resection as shown in Figure 5. We reviewed the cases performed by this resident and they did not seem to be more difficult based on body mass index, tumor size or previous laparotomy. Therefore, this study also shows that not only performing a certain number of resections is important to master laparoscopic colectomy but also that a specific talent is needed for an acceptable outcome. Apparently, the supervision could not prevent complications, because these mainly concerned postoperative anastomotic leakage and too few lymph nodes, making interpretation of the data more difficult. Grantcharov showed in a study to determine learning patterns for basic laparoscopic technical skills that 3 out 37 (8\%) surgical residents underperformed. These 3 probably reflect a group of residents who are unable to learn the laparoscopic technique.\textsuperscript{22} CUSUM analysis seems an effective way of analyzing an individual resident’s surgical progress with the possibility of an early identification of underperformance.

We conclude that in mastering laparoscopic sigmoid resections an early learning curve for surgical residents can be measured and a steady state can be reached at approximately 11 procedures. Furthermore, not every resident seems to have the necessary abilities to adequately learn a laparoscopic sigmoid resection, and therefore CUSUM analysis of individual residents might be a suitable way of assessing their performance.

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\textbf{FIGURE 4.} Moving average mean blood loss by case number (all residents together).

\textbf{FIGURE 5.} Success rate for laparoscopic sigmoid resection as a function of the number of cases. The curves represent the cumulative sum analysis (CUSUM) for 13 surgical residents, calculated for a target success of 85\%. Upward slopes indicate the resident is not meeting the acceptable failure rate. Downward slopes indicate that the rate of failures falls within the acceptable range.


