

ONLINE FIRST

# Technical Proficiency in Hand-Assisted Laparoscopic Colon and Rectal Surgery

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Audio Interview

## Determining How Many Cases Are Required to Achieve Mastery

Rajesh Pendlimari, MBBS; Stefan D. Holubar, MD; Eric J. Dozois, MD;  
David W. Larson, MD; John H. Pemberton, MD; Robert R. Cima, MD, MA

**Objective:** To determine how many cases are required to achieve technical proficiency for hand-assisted laparoscopic surgery (HALS).

**Design:** Retrospective study.

**Setting:** Tertiary care hospital.

**Patients:** Using a prospective database, all HALS colorectal resections from 2003 to 2009 by 2 surgeons (A and B) were reviewed. Over 6 years, surgeons A and B performed 397 and 322 cases.

**Interventions:** Change-Point Analysis (CUSUM) was used to define the number of cases required to effect improvement in operative time. Cases before and after the change point were considered as being in the “learning period” and “skilled period.”

**Main Outcome Measures:** Operative time; short-term outcomes.

**Results:** The change point occurred after 108 and 105 cases for surgeons A and B, respectively. The learning period and skilled period were similar with respect to age,

sex, body mass index, prior abdominal surgery, medical comorbidities, and American Society of Anesthesiologists class. Mean overall operative time decreased from 263 to 185 minutes ( $P < .001$ ). The decrease in mean operative duration for specific resections were as follows: right colectomy, 35 minutes ( $P = .003$ ); left colectomy, 63 minutes ( $P = .006$ ); sigmoid colectomy, 63 minutes ( $P < .001$ ); anterior resection, 70 minutes ( $P < .001$ ); coloanal anastomosis, 52 minutes ( $P = .003$ ); subtotal colectomy, 75 minutes ( $P < .001$ ); and total proctocolectomy with ileal reservoir, 80 minutes ( $P < .001$ ). Intraoperative complications and conversion rate were similar, but overall morbidity, infectious complications, readmissions, and length of stay were all significantly ( $P < .05$ ) lower during the skilled period.

**Conclusions:** For HALS colorectal resection, technical proficiency occurred after approximately 105 cases, and increased surgeon experience resulted in improved short-term outcomes. These data suggest that the learning curve for HALS colorectal resection will extend beyond fellowship training for many colorectal surgeons.

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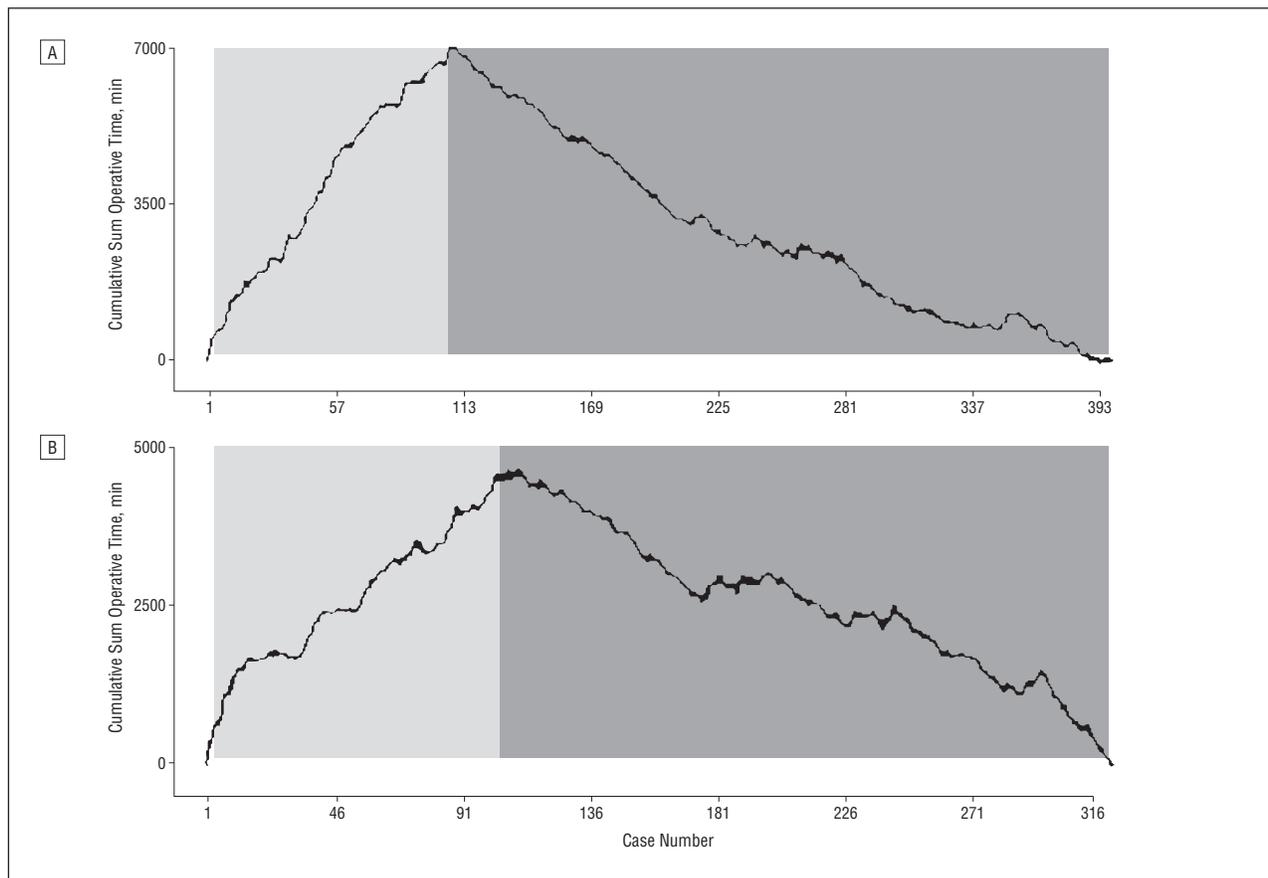
**Author Affiliations:** Division of Colon and Rectal Surgery, Mayo Clinic, Rochester, Minnesota (Drs Pendlimari, Dozois, Larson, Pemberton, and Cima); and Department of Colon and Rectal Surgery, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire (Dr Holubar).

**H**AND-ASSISTED LAPAROSCOPIC surgery (HALS) has emerged as a popular technique in minimally invasive surgery, though it is often viewed as a bridging technique between open surgery and straight laparoscopic surgery. Hand-assisted laparoscopic surgery has gained popularity for disadvantages associated with laparoscopic-assisted colectomy (LAC) including a steep learning curve, long operative times, and lack of tactile feedback.<sup>1-3</sup> Currently, LAC is estimated to be performed in approximately 30% of colon cancer cases in the United States.<sup>4,5</sup> Achieving technical competency is essential for performing laparoscopic surgery, especially for oncological and pelvic resections. Technical

competency for experienced laparoscopic surgeons to perform oncological resection was defined as 20 benign LAC cases in the COST trial.<sup>6</sup>

### See Invited Critique at end of article

Previously, we have reported that the outcomes of HALS in colon and rectal surgery are similar to LAC.<sup>1,3</sup> While HALS is accepted as an alternative to laparoscopic surgery by some surgeons, others view it as a stepping-stone to LAC proficiency, while others specifically use this technique for more complex cases. Several studies have been published that define the laparoscopic learning curve.<sup>7-12</sup> Al-



**Figure 1.** Change-Point Analysis to detect change with 100% confidence for surgeons A and B (CUSUM analysis with 1000 bootstraps). A, change is identified at the 108th case for surgeon A with 100% confidence. B, Change is identified at the 105th case for surgeon B with 100% confidence. Values during the slope upward tend to be higher than average and values during the slope downward tend to be lower than average. In the light gray area, the values are in increasing order or at the same level. In the dark gray area, the values are in decreasing order or at the same level.

though HALS is considered a less difficult technique to learn than straight laparoscopic colectomy, limited literature exists on HALS learning curves.<sup>13-15</sup>

It has been shown that a minimum of 25 HALS cases are required to master the learning curve for HALS colectomy.<sup>12</sup> In modern group practice, surgeons often compliment each other by sharing their technical knowledge and skills and surgeons who are late adopters of LAC may be introduced to laparoscopy via HALS. In addition, some surgical educators feel HALS colon and rectal resection may benefit surgical resident education by allowing more hands-on time than LAC.

Realizing the increasing national trends in minimally invasive surgery—performed colectomies, residency training oversight committees have increased the minimum case volume requirements for trainees while in residency. The General Surgery Residency Review Committee, part of the Accreditation Council for Graduate Medical Education, recently raised the minimum number of basic laparoscopic procedures from 34 to 60, and a total of 25 complex laparoscopic procedures were mandated for general surgery residents for graduation. Similarly, the 2011 Colorectal Residency Review Committee requirements mandate a total of 30 laparoscopic colectomies for colorectal fellows. The American Board of Colon and Rectal Surgery requires a minimum of 50 laparoscopic colectomies to be eligible to sit for the certifying examination. Currently, there

is significant debate regarding case volume alone as a reflection of technical competency but these increased requirements represent a more realistic view of achieving competency for minimally invasive surgery procedures. It is currently unclear if volume of cases performed is sufficient to achieve proficiency as reflected by quality patient outcomes.

To gain further insights into the learning experience for HALS colon and rectal surgery, we aimed to describe how many cases were required to achieve significant improvement in operative times by 2 high-volume HALS surgeons over a 6-year period.

## METHODS

After approval from the Mayo Clinic institutional review board, the data of all HALS patients from 2003 to 2009 were obtained from retrospective review of our prospectively maintained colorectal divisional database. The entire divisional experience and short-term outcomes are described in earlier publications.<sup>1-3</sup>

In this current study, we examined cases from 2 (of 8) board-certified colorectal surgeons (surgeons A and B) who preferentially use HALS. Surgeon A had formal fellowship training in laparoscopic surgery and occasionally performs LAC for right colectomy and small-bowel resection, while surgeon B had no formal laparoscopic training and uses the HALS technique exclusively for minimally invasive cases.

A total of 719 patients were operated on using HALS by both surgeons during the study period. Demographics reported are age, sex, body mass index, surgical indications, surgical history, and American Society of Anesthesiologists score. Operative variables include operative time, conversion rate, intraoperative complications, and estimated blood loss. Operative time is defined as the time from incision to closure of the wound. A general surgery resident or a clinical colorectal fellow is always part of the surgical team during these surgeries. Conversion to open surgery is defined as lengthening of the incision beyond 10 cm. Postoperative short-term (30-day) outcomes include the length of postoperative hospital stay, readmission rate and reoperation rate, overall morbidity, and infectious complications. Overall morbidity included partial small-bowel obstruction, small-bowel obstruction, anastomotic leak, intra-abdominal abscess, wound complications, urinary retention (requiring recatheterization), or any medical complications.

## STATISTICS

The changes in operative time were detected using Change-Point Analysis (Taylor Enterprises, Inc).<sup>16</sup> Change-Point Analysis is a variant of CUSUM analysis that was developed to detect significant changes in the time series data.<sup>16-18</sup> Change-Point Analysis uses CUSUM (commonly used to analyze learning curves) analysis with bootstrapping (1000 bootstraps) to identify the changes. The CUSUM chart is a type of sequential analysis obtained by plotting cumulative sums of deviation from the mean, whereas bootstrapping minimizes the statistical noise.<sup>19</sup> Change-Point Analysis also reduces the number of false detections by controlling the changewise error rate and is also a powerful tool to detect small and sustained and multiple changes. The 1000 bootstraps used in this analysis potentially correct for the confounding extreme variables resulting from the highly variable case mix. For ease of interpretation, the values during the upward slope tend to be more than average and values during the downward slope tend to be less than average.

In this study, we applied this statistical method to evaluate changes in the operative time of 2 high-volume HALS surgeons, which led us to divide the groups into "learning period" (P1) and "skilled period" (P2) rather than based on a fixed count.

Statistical analyses were performed using JMP software version 8.0 (SAS Institute Inc). Continuous variables are reported as either mean and standard deviation or median and categorical variables, as frequency and proportion. The Fischer exact test or Wilcoxon rank test was used to assess the differences between the groups.

## TECHNIQUE

The technical details of hand-assisted laparoscopic colorectal surgery have been detailed in previous publications.<sup>1-3</sup>

## RESULTS

For surgeon A, the change point occurred at the 108th case and for surgeon B, the change point occurred at the 105th case. Changes were identified with 100% confidence (**Figure 1**). The 2 surgeons differed in their practice in that surgeon A had a more inflammatory bowel disease–predominant practice (39.3% vs 25.2%;  $P < .001$ ) while surgeon B had a more oncological-predominant practice (44.1% vs 28.5%;  $P < .001$ ). It took

**Table 1. Demographics and 30-Day Outcomes Before and After Change Point**

Variables	No. (%)		P Value
	P1 (n = 213)	P2 (n = 506)	
Age, y, mean (SD)	53.4 (17.9)	55.7 (17.2)	.11
Women	95 (44.6)	243 (48)	.41
BMI, mean (SD)	27 (5.5)	27.1 (5.6)	.98
Prior medical comorbidities	43 (20.2)	110 (21.7)	.69
Prior abdominal surgery	88 (41.3)	233 (46.1)	.25
Diagnosis			
Inflammatory bowel disease	79 (37.1)	158 (31.2)	.14
Cancer	68 (31.9)	187 (37)	.20
Diverticular disease	36 (16.9)	97 (19.2)	.53
Other <sup>a</sup>	30 (14.1)	64 (12.7)	.63
ASA index III/IV	68 (31.9)	164 (32.4)	.93
Operative time, min, mean (SD)	263 (86)	185 (67)	<.001
Intraoperative complications	15 (7)	42 (8.7)	.55
Estimated blood loss, mL <sup>3</sup> , median	150	100	.009
Conversions	19 (8.9)	41 (8.1)	.77
Overall morbidity	72 (33.8)	126 (24.9)	.02
Infectious complications	27 (12.7)	35 (6.9)	.02
Readmissions	22 (10.3)	28 (5.5)	.03
Reoperations	7 (3.3)	17 (3.4)	.58
Length of hospital stay, d, mean (SD)	7 (6.3)	6.4 (6.7)	<.001

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); P1, learning period; P2, skilled period.

<sup>a</sup>For example, familial adenomatous polyposis, slow-transit constipation, rectal prolapse, volvulus, incisional hernia, and abdominal wall fistula.

33 and 28 months for surgeon A and surgeon B to reach P2, respectively.

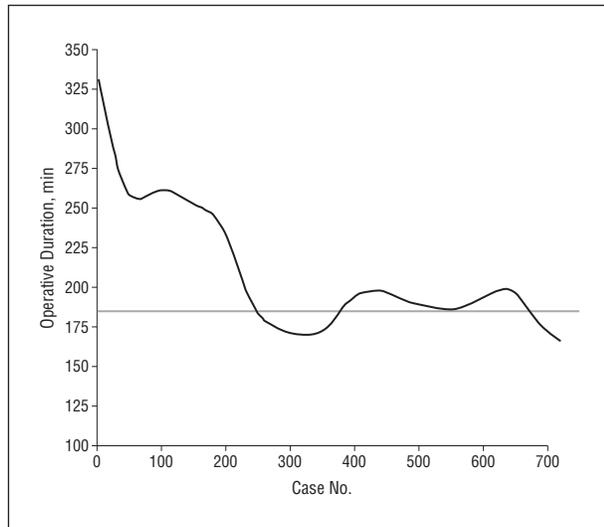
A total of 213 patients were operated on in P1 and demographic, operative, and short-term (30-day) outcome variables are reported in **Table 1**. Demographics such as age, sex, body mass index, previous abdominal surgery, prior medical comorbidities, and American Society of Anesthesiologists index were not significantly different between patients in P1 and P2. In terms of intraoperative variables, the conversion rate and intraoperative complications were also not different between periods, although median estimated blood loss decreased from 150 mL<sup>3</sup> in P1 to 100 mL<sup>3</sup> in P2 ( $P = .009$ ) and overall operative duration decreased from 263 minutes in P1 to 185 minutes in P2 ( $P < .001$ ) (**Table 2**). There were more patients with ulcerative colitis (31% vs 22.3%;  $P = .02$ ) in P1, and more total proctocolectomy with ileal reservoirs were done in P1 (32.4% vs 21.2%;  $P = .002$ ).

Short-term (30-day) outcome improved from P1 to P2 with a decrease in overall morbidity, infectious complications, readmission rate, and hospital length of stay. The reoperation rate did not significantly differ. The operative duration graph over time demonstrated an initial steep decline followed by a gradual decline (**Figure 2**). In **Figure 3**, the similar operative duration graphic curves for right hemicolectomy, left hemicolectomy, sigmoid colectomy, anterior resection, subtotal colectomy, and total proctocolectomy are shown.

**Table 2. Operative Duration**

Procedures	P1		P2		P Value <sup>a</sup>
	Operative Duration, min, Mean (No. of Cases)	95% CI	Operative Duration, min, Mean (No. of Cases)	95% CI	
Surgeons A and B					
Overall	263 (213)	251-274	185 (506)	179-191	<.001
Right colectomy	174 (17)	148-201	139 (72)	128-150	.003
Left colectomy	227 (7)	195-259	164 (18)	138-191	.006
Sigmoid colectomy	209 (44)	190-228	146 (106)	137-155	<.001
Anterior resection	231 (21)	199-262	169 (64)	155-182	<.001
Coloanal anastomosis	266 (17)	242-290	214 (28)	191-236	.003
Subtotal colectomy	284 (21)	249-319	205 (58)	192-219	<.001
Total proctocolectomy	333 (69)	317-350	253 (107)	242-264	<.001
Surgeon A overall	270 (108)	253-288	182 (289)	174-189	<.001
Surgeon B overall	255 (105)	239-270	190 (217)	180-199	<.001

Abbreviations: CI, confidence interval; P1, learning period; P2, skilled period.  
<sup>a</sup> P values adjusted for multiple comparisons (Bonferroni correction).



**Figure 2.** Learning curve of surgeons A and B, overall operative time. The mean (horizontal line) and 95% confidence interval of “after change point” are marked in the graph. The smoother curve is a cubic spline with  $\lambda=0.05$  and standardized X values.

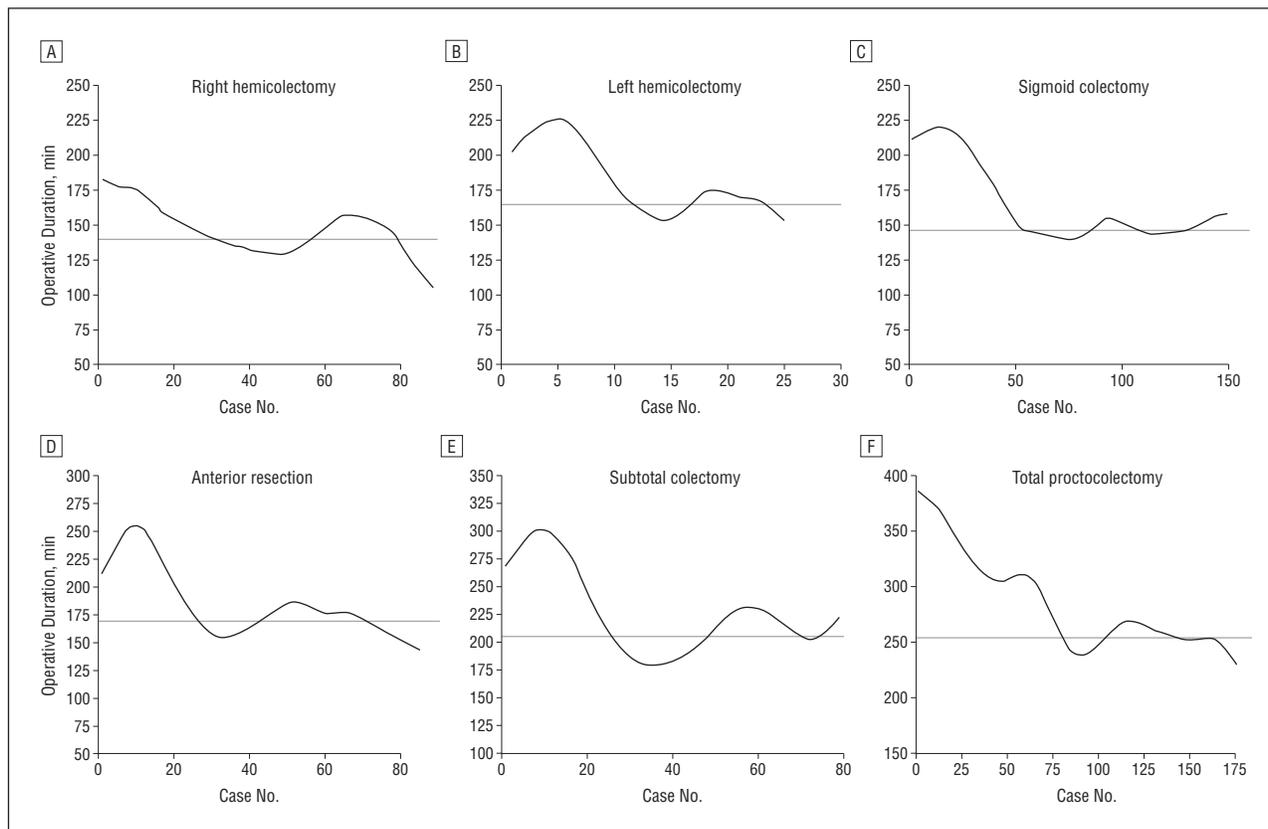
**COMMENT**

The learning curves associated with minimally invasive surgery techniques such as LAC and HALS have previously been described in the literature and have focused on competency.<sup>4,7-12,14,20-22</sup> However, proficiency, as opposed to competency, implies attainment of some level of mastery of the technique that comes with increased experience and results in improved outcomes rather than the bare minimum needed to complete an operation safely. Achieving proficiency associated with the technique appears to occur over a longer period and increased volume of cases. This study demonstrates that in the practice of 2 high-volume HALS surgeons, technical proficiency, defined by improved operative times and short-term outcomes, for HALS colectomy occurs after performing approximately 100 cases. This is in

contrast to the lower number reported for technical competency.<sup>13,14</sup>

In the present study, the overall operative duration as a primary end point declined by 78 minutes ( $P < .001$ ) in P2. The overall morbidity, infectious complications, length of stay, and readmission rate were also lower in P2. When graphically observed, operative duration had a steep decline initially followed by a lesser steep decline before flattening of the learning curve. Operative duration may be a poor surrogate marker for the laparoscopic learning curve.<sup>23</sup> Instead, the postoperative outcomes and rates of readmission may be recommended for better surrogates for the learning curve. The data presented herein help to validate the observation that operative duration represents a technical end point whereas postoperative outcomes and readmission rate represent an overall quality-of-care end point. Postoperative outcomes and readmission rates are not only dependent on the technique of the surgery but also on the diagnosis, their functional status, and postoperative care. We believe conversion is mainly dependent on disease, preoperative variables (obesity), or intraoperative complications (eg, bleeding). The learning curve not only represents a technical aspect but also a quality aspect. While the technical aspect is logically assessed with operative time, the quality aspect is assessed by the short-term outcomes. In this study, we showed that overall 30-day complications were reduced significantly, as were readmissions, infectious complications, and the length of hospital stay. The study by Ozturk et al<sup>14</sup> showed that quality indicators were not improved during the initial HALS experience despite a steady decline in operative times. The reduction in operative times should be clinically important, not just related to decreased operative time, which was clearly associated with an increased risk of postoperative complications including an increased risk of surgical site infections.<sup>24,25</sup> Thus, the reduced complication rate in P2 may also be partially attributed to the shortened operative duration.

Schadde et al<sup>15</sup> initially described that the operative time was longer for the initial 30 cases, and conversion



**Figure 3.** Learning curve for various procedures. A, Right hemicolectomy. B, Left hemicolectomy. C, Sigmoid colectomy. D, Anterior resection. E, Subtotal colectomy. F, Total proctocolectomy. The mean (horizontal line) and 95% confidence interval of "after change point" are marked in the graph. The smoother curve is a cubic spline with  $\lambda=0.05$  and standardized X values.

rates reached a steady state after 30 cases. This study represented mostly segmental colectomies. Subsequently, Kang et al<sup>13</sup> described that the learning curve comprises 21 to 25 cases to achieve competency for HALS from a single surgeon's experience. Ozturk et al<sup>14</sup> described the learning curve of an individual surgeon over the first 200 HALS cases. The cases were categorized into groups of 25 in chronological order and no differences were identified for overall operative duration or postoperative outcomes. The only differences were the significant decline in operative duration for left colectomy and total colectomy. As each surgeon begins his or her career with different levels of laparoscopic surgery experience, recommendations for a minimum number of procedures to attain competency and certainly for proficiency must be guarded.

It is possible that training in simulation laboratories may allow residents to achieve proficiency with fewer cases.<sup>26</sup> It is also well known that younger surgeons more readily acquire laparoscopic skills.<sup>27</sup> Although 25 cases, as suggested by earlier studies, likely represents the minimal number needed to become acquainted with HALS colectomy, it requires about 100 cases to reach mastery as marked by not only safely completing the operations but in having a quality clinical outcome as demonstrated in our data. The current recommendation for graduates in colon and rectal surgery is 75 complex laparoscopic procedures (including general surgery and colon and rectal surgery training). Our data suggest, however, that for colorectal surgeons going into practice after

their fellowship, additional cases will be required until proficiency and optimal outcomes are attained.

The learning curves from both surgeons in this study appear similar and suggest the tools used to document those curves are valid. Skill variability exists between individuals based on their prior experience, training, inherent ability, and laparoscopic skills. Both surgeons in this study differed in their laparoscopic training, laparoscopic experience, and open surgery experience. Because of the retrospective nature of the study, the type of operations done and the initial patient selection were controlled. In other words, this experience depicts the experience of the surgeons who adopted HALS as the primary modality of minimally invasive surgery after fellowship. In the initial period, HALS was more significantly used for total proctocolectomy because of the significantly higher number of patients with ulcerative colitis and that may have skewed the learning curve slightly toward the left.

In conclusion, operative duration decreased with experience as did the intraoperative estimated blood loss, overall morbidity, infectious complications, readmissions, and hospital length of stay. Increased proficiency in HALS as measured with operative duration improved the postoperative outcomes. Achieving technical competency and mastery are 2 different end points and these findings suggest that mastery of the HALS colorectal technique will, for many surgeons, occur after fellowship training.

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Correspondence: Robert R. Cima, MD, MA, Mayo Clinic College of Medicine, 200 1st St SW, Rochester, MN 55905 (cima.robert@mayo.edu).

**Author Contributions:** *Study conception and design:* Pendlimari, Holubar, Dozois, Larson, Pemberton, and Cima. *Acquisition of data:* Pendlimari. *Analysis and interpretation:* Pendlimari. *Drafting of the manuscript:* Pendlimari, Holubar, and Dozois. *Critical revision of the manuscript for important intellectual content:* Dozois, Pemberton, Larson, and Cima. *Statistical analysis:* Pendlimari. *Administrative, technical, and material support:* Pendlimari, Dozois, Larson, and Cima. *Study supervision:* Holubar, Dozois, Larson, and Pemberton.

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## INVITED CRITIQUE

### ONLINE FIRST

# Proficiency, Competency, and Mastery

## Where Are You on the Learning Curve?

This article<sup>1</sup> and many others suggest that the number of cases needed to achieve mastery in HALS is 105.<sup>2-4</sup> These studies face a number of limitations in their approach including different

demographics of the study population, the age of the operating surgeon as well as his or her surgical experience, and the varying difficulty of the operations themselves.<sup>5,6</sup>