
Learning Curve for Single-Incision Laparoscopic Anterior Resection for Sigmoid Colon Cancer



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- BACKGROUND:** Compared with conventional laparoscopic surgery, single-incision laparoscopic surgery produces better cosmetic benefits. The aim of this study was to investigate the learning curve for single-incision laparoscopic anterior resection (SILAR) for sigmoid colon cancer using multidimensional methods.
- STUDY DESIGN:** From September 2009 through May 2014, one hundred and thirteen patients underwent SILAR for sigmoid colon cancer by a single surgeon at Severance Hospital. The learning curve was analyzed using moving average, cumulative sum control chart (CUSUM), and risk-adjusted CUSUM methods. For risk-adjusted CUSUM, surgical failure was defined as conversion to open surgery or conventional laparoscopic surgery, morbidity within 30 days after surgery, <12 harvested lymph nodes, or local recurrence.
- RESULTS:** Using the moving average method, the peak point for operation time occurred at the 65th case (173 minutes). The CUSUM method also showed the operation time peak point at the 65th case. However, the risk-adjusted CUSUM curve did not ascend after the 61st case. The operation time and hospital stay for the 60 phase 1 patients (cases 1 to 60) were longer than for 53 phase 2 patients (cases 61 to 113) (166.6 vs 140 minutes; $p < 0.001$ and 7.1 vs 5.5 days; $p = 0.009$). Phase 2 patients had a significantly larger tumor diameter and more harvested lymph nodes.
- CONCLUSIONS:** The learning curve for SILAR for sigmoid colon cancer was 61 to 65 cases according to multidimensional statistical analyses. Single-incision laparoscopic anterior resection is feasible for surgeons experienced in laparoscopic surgery. However, SILAR required more cases for proficiency than the number previously reported for conventional laparoscopic surgery, likely because of its technical challenges. (J Am Coll Surg 2015;221:397–403. © 2015 by the American College of Surgeons)
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Laparoscopic surgery (LS) is an option for colorectal cancer, producing similar oncologic outcomes and better short-term outcomes compared with open surgery.¹⁻³ Both surgeons and patients prefer shorter incisions, with their associated better cosmetic results, if similar or better outcomes can be achieved. However, conventional LS

with multiple incisions is associated with potential complications, including hematomas and incisional hernias.^{4,5} Against this backdrop, numerous colorectal surgeons have begun to perform single-incision laparoscopic surgery (SILS) for colorectal cancer.

Single-incision laparoscopic surgery for colorectal disease produces similar perioperative outcomes and shorter total incision length compared with conventional LS.⁶⁻¹¹ A few authors have reported oncologic outcomes after performing SILS for malignancy.¹² However, SILS can be difficult and confusing even for LS-experienced surgeons because of collisions between surgical instruments or overlap between the operator and the assistant. This causes many colorectal surgeons to be hesitant about performing SILS, although several articles have reported comparable outcomes with those achieved with conventional LS. Therefore, data are required on the learning

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Abbreviations and Acronyms

CUSUM	= cumulative sum control chart
LC	= learning curve
LOS	= length of stay
LS	= laparoscopic surgery
OS	= open surgery
OT	= operation time
RA-CUSUM	= risk-adjusted cumulative sum control chart
SILAR	= single-incision laparoscopic anterior resection
SILS	= single-incision laparoscopic surgery

curve (LC) for SILS for colorectal disease to clarify the benefits of the procedure and the ability of surgeons to adapt to it. There are no published reports about the LC for single-incision laparoscopic anterior resection (SILAR), although there have been a few previous reports about the LC for SILS right hemicolectomy.¹³⁻¹⁵ The aim of this study was to investigate the LC for SILAR for sigmoid colon cancer using the following statistical methods: moving average method, cumulative sum control chart (CUSUM), and risk-adjusted (RA) CUSUM.

METHODS**Patients**

From September 2009 through May 2014, one hundred and twenty-six patients underwent elective SILAR for sigmoid colon cancer by a single surgeon (HH) at Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea. Before beginning to use the SILAR technique, the surgeon had performed >100 open surgery (OS) and conventional LS procedures for colorectal cancer. All patients were older than 19 years of age and diagnosed pathologically with adenocarcinoma. The sigmoid colon was defined clinically as the region between the rectosigmoid junction and the descending colon, as described in our previous study.¹² Only patients presumed to have a clinical stage <T3N0 underwent SILAR in the early years of the study, but advanced cases were included in the later years. After the surgeon provided appropriate information about both SILAR and conventional laparoscopic anterior resection to the patients, only those patients who were interested in undergoing SILAR and who signed the informed consent document were included. Patients who simultaneously underwent other surgery were excluded from the study (n = 13) to reduce confounding factors that can affect outcomes. Patient data were collected prospectively and reviewed retrospectively.

Perioperative and pathologic outcomes

For analysis of baseline characteristics and perioperative outcomes, the following variables were analyzed: sex, age, BMI, alcohol intake, smoking status, American Society of Anesthesiologists physical status classification, previous abdominal surgery, neoadjuvant and adjuvant chemotherapy, tumor location, operation time (OT), blood loss, transfusion, time to resumption of soft diet, hospital length of stay (LOS), incision length, conversion to conventional LS or OS, and postoperative morbidity and mortality. Conversion was defined as the insertion of additional port(s) (LS) or unplanned extension of the incision beyond that required for specimen extraction (OS). Additionally, the tumor diameter, number of harvested lymph nodes, proximal and distal resection margins, clinical stage according to the American Joint Committee on Cancer guidelines (7th ed), and local recurrence were recorded to investigate pathologic outcomes. The surgical technique was described in detail in our previous study.¹²

Statistical analysis

Categorical variables were analyzed by chi-square test or Fisher's exact test, and continuous variables were analyzed by the Student's *t*-test or Mann-Whitney test. A *p* value <0.05 was considered statistically significant. The LC was evaluated for OT alone by the moving average method and CUSUM, and RA-CUSUM evaluated the success of surgery for a more appropriate analysis of the LC. Surgical failure was defined as the presence of any of the following: conversion, complications that required any surgical intervention under general anesthesia (ie, more than grade IIIa of the Clavien-Dindo classification¹⁶), <12 harvested lymph nodes, or local recurrence. All statistical analyses were performed using Statistical Package for the Social Sciences (version 20.0, IBS SPSS) and R package (version 3.1.2., The R Project for Statistical Computing). We used the moving average method, CUSUM, and RA-CUSUM methods in our previous report¹⁷ to analyze the LC of robotic low anterior resection for rectal cancer, although the specific parameters differed from those used in the current report.

Moving average method

The moving average is a method to analyze data points by creating a series of averages of different subsets of the full dataset. It is used with time series data to smooth out short-term fluctuations and highlight longer-term trends or cycles. We applied the method to the OT of SILAR, with a moving average order of 20 cases as follows:

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