Competence versus mastery: The time course for developing proficiency in video-assisted thoracoscopic lobectomy

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Objectives: Thoracoscopic lobectomy has a vaguely defined learning curve for competency, whereas the development of proficiency has not been evaluated. We compared learning curves for 2 surgeons experienced in open lobectomy to define the learning process for thoracoscopic lobectomy.

Methods: The first 200 patients who underwent thoracoscopic lobectomy by 1 senior surgeon at 2 different institutions were evaluated. Data were abstracted from prospectively maintained databases. Learning curves were evaluated for operative time, blood loss, and postoperative length of stay by assessing elements of proficiency: efficiency (defined as decreasing values for these variables, assessed by Change-Point Analysis) and consistency (defined as the absence of outliers, evaluated by moving average). Conversion to open rates and complication rates were assessed.

Results: Surgeon A's patients were younger than Surgeon B's patients (57.4 vs 66.0 years; $P < .001$) and had fewer medical comorbidities. For Surgeons A and B, operation time (mean, 178 vs 180 minutes) efficiency was achieved at 157 and 108 cases, respectively, and blood loss (mean 181 vs 178 mL) efficiency was achieved at 126 and 139 cases, respectively. Conversion to open rates decreased between the first and second halves of the study ($P < .001$) despite expanding anatomic indications for a video-assisted thoracic surgery approach. Consistency was not reliably achieved for either surgeon for operating time or blood loss. Postoperative length of stay and complication rates did not change for either surgeon.

Conclusions: The learning curves for video-assisted thoracoscopic lobectomy were similar for both surgeons. Between 100 and 200 cases are required to achieve efficiency, and consistency requires even more cases. (J Thorac Cardiovasc Surg 2014;147:1150-4)

Competence is the benchmark by which physicians are permitted to perform procedures independently. Developing competence in a complex operation entails performing a sufficient number of procedures to demonstrate consistent safety and efficacy. For minimally invasive lobectomy, this appears to require a minimum of 20 to 30 cases, with estimates as high as 50 operations.[1-4] Progressing to proficiency in a complex procedure not only necessitates substantial additional operative experience but also requires a qualitative leap in knowledge and performance.[5] Two measures that characterize proficiency are efficiency and consistency. The learning curves that describe the achievement of proficiency are likely to be different than those for developing competency.

Determining the time and case number required to attain procedural proficiency is important for many reasons. When feasible, newly trained surgeons should be mentored until they demonstrate skills and outcomes that exceed those required for competency, and the time and manpower needed for such supervision need to be appropriately allocated. It is possible that medical–legal risk exposure and associated malpractice payments ultimately might be assessed on the basis of level of expertise, and knowledge of the duration of increased risk would help correctly apportion individual contributions. Understanding the time and caseload required to develop proficiency permits assessment of whether simulation or intense mentorship is able to shorten the duration of the learning curve.

We studied learning curves for video-assisted thoracic surgery (VATS) lobectomy to determine how long it takes to achieve proficiency by analyzing both intraoperative and postoperative factors for efficiency and consistency. We also assessed whether developing efficiency and consistency require similar time frames.

MATERIALS AND METHODS

The first 200 patients who underwent planned VATS lung resection by each of 2 senior surgeons at different institutions were evaluated. Major lung resections performed using an open thoracotomy also were catalogued for the same time period. Both surgeons had extensive prior experience with VATS before they began doing VATS lung resections and had

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Abbreviations and Acronyms

CUSUM = cumulative sum
EBL = estimated blood loss
VATS = video-assisted thoracic surgery

extensive prior experience with open lung resection. Patients were included in the VATS analysis who had surgery for benign or malignant lung disease. Patients were excluded who underwent concomitant chest wall resection via VATS or robotic-assisted VATS. VATS lung resection was defined as lobectomy. VATS lung resection was performed using a 3-incision approach, including 2 ports and an access incision up to 5 cm in length, without rib spreading, with or without lymph node dissection as appropriate for the underlying disease.

Data were abstracted from prospectively maintained and internal review board–approved databases. Patient consent for this study was waived. Patient demographics and preoperative clinical factors were identified. Intraoperative data and details regarding the pathology specimen were collected. Conversion to an open procedure was defined as emergency or elective thoracotomy, regardless of length and that included rib spreading, during the VATS procedure. Pathologic staging,[6] postoperative length of stay, and postoperative complications were analyzed. Operating time was defined as the time from incision to the time of skin closure. Estimated blood loss (EBL) was based on estimates by the surgeon and anesthesiologist. Postoperative complication data were collected from the hospital record prospectively and categorized as pulmonary (pneumonia, prolonged postoperative intubation, reintubation, lung collapse requiring bronchoscopy, acute respiratory distress syndrome), cardiovascular (pulmonary embolism, myocardial infarction, arrhythmia requiring intervention), and other. Operative mortality was defined as death occurring during hospitalization for lung surgery or within 30 days of the operation.

Statistical analyses were performed using Statistical Product and Service Solutions version 13.0 (SPSS Inc, Chicago, Ill). Continuous variables are reported as mean and standard deviation, and categoric variables are reported as frequency and proportion. Chi-square analysis or the Fisher exact test was used to assess differences in categoric data, and the *t* test or Wilcoxon rank test was used to assess the differences between continuous variables. The changes in operative times, EBL, and length of stay were assessed using Change-Point Analysis (Taylor Enterprises, Inc, Libertyville, Ill) with bootstrapping (1000 bootstraps) for evaluation of efficiency. Change-Point Analysis is a variant of cumulative sum (CUSUM) analysis that was developed to detect significant changes in time series data. For interpretation of graphic representations, values on the upward slope of a Change-Point curve tend to be greater than average, and values on the downward slope of a curve tend to be less than average. Analysis was also performed with the moving average technique to assess consistency by identifying outliers, using means and standard deviations of data for the last 50 patients of each surgeon as the limits to which the data were compared. The sample size and moving average length were both set at 10, resulting in 20 sampled intervals for the 200 patients, and outliers were identified that were greater than 1 standard deviation from the mean.

RESULTS

A total of 400 patients were evaluated for this study. Surgeon A began performing VATS lobectomy in September 2006 and completed 200 attempted cases by May 2010, an interval of 43.2 months. Surgeon B began performing VATS lobectomy in March 2007 and completed 200 attempted cases by October 2012, an interval of 68.6 months. Patient characteristics are listed in Table 1. The patient populations differed in a number of characteristics, including age, gender, and medical comorbidities. There were no differences between the groups in performance status or baseline lung function.

Surgical outcomes are listed in Table 2. There were similarities in types of operations, operative times, and surgical blood loss. Resection was performed more often for cancer by Surgeon B, and those operations were more often performed for earlier-stage disease. Clinical tumor size was similar for both surgeons. Length of stay was longer for Surgeon A. Conversion and incidence of complications were more common for Surgeon B. Surgeon A's conversion rates were 7% and 1% in the first and second halves of the study, respectively ($P = .03$), and Surgeon B's conversion rates were 19% and 4%, respectively ($P = .001$). Complication rates for Surgeon A (7% and 11%, $P = .32$) and Surgeon B (28% and 20%, $P = .19$) were similar for both periods.

We grouped VATS and open cases by VATS 50-case intervals to examine whether surgeon selection of cases changed over the period of study (Table 3). The percentage of VATS cases pathologically staged greater than I or II increased significantly during the period of study. Tumor diameter trended upward during the period of study, but the differences did not reach statistical significance. Open cases performed during the study period (158) were classified according to indication as reoperation (21), induction chemoradiotherapy (26), robotic resection (4), and anatomy (central location, tumor size, extent of nodal involvement, suspected mediastinal or chest wall involvement, pneumonectomy; 107). The percent of cases performed open because of anatomic causes significantly decreased during the study period.

Change-Point analysis demonstrated that the inflection point for operating time for Surgeon A occurred at patient 157 (99% confidence; case numbers 128-173), and the primary inflection point for Surgeon B occurred at patient 108 (100% confidence; case numbers 90-120; Figure 1). For EBL, the inflection point for Surgeon A occurred at patient 126 (100% confidence; case numbers 96-148), whereas for Surgeon B the primary inflection point occurred at patient 139 (100% confidence; case numbers 132-153).

We grouped cases by 2-month time intervals to investigate whether the time interval or case number is more important in reaching a Change-Point. The inflection point for operating time for Surgeon A occurred at time interval 19 (99% confidence; time intervals 17-20), at which point Surgeon A had performed approximately 160 cases. In comparison, the primary inflection point for operating time for Surgeon B occurred at time interval 20 (100% confidence; time intervals 17-21), at which time Surgeon B had performed approximately 110 cases. Inflection points for EBL were at time interval 17 (~130 cases) for Surgeon