Learning curve of totally thoracoscopic pulmonary segmentectomy

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Abstract Totally thoracoscopic pulmonary segmentectomy (TTPS) is a feasible and safe technique that requires advanced thoracoscopic skills and knowledge of pulmonary anatomy. However, data describing the learning curve of TTPS have yet to be obtained. In this study, 128 patients who underwent TTPS between September 2010 and December 2013 were retrospectively analyzed to evaluate the learning curve and were divided chronologically into three phases, namely, ascending phase (A), plateau phase (B), and descending phase (C), through cumulative summation (CUSUM) for operative time (OT). Phases A, B, and C comprised 39, 33, and 56 cases, respectively. OT and blood loss decreased significantly from phases A to C (P < 0.01), and the frequency of intraoperative bronchoscopy for target bronchus identification decreased gradually (A, 8/39; B, 4/33; C, 3/56; P = 0.06). No significant differences were observed in demographic factors, conversion, complications, hospital stay, and retrieved lymph nodes among the three phases. Surgical outcomes and techniques improved with experience and volume. CUSUMOT indicated that the learning curve of TTPS should be more than 72 cases.

Keywords thoracoscopic; segmentectomy; learning curve; CUSUM

Introduction

Since pulmonary segmentectomy was first applied to treat bronchiectasis in 1939 [1], it has been considered a versatile resection procedure that can be diagnostic and therapeutic in the setting of indeterminate pulmonary nodules, metastatic cancer, and stage IA non-small cell lung cancer (NSCLC) [2]. Compared with lobectomy, segmentectomy is associated with equivalent oncologic outcomes in stage IA NSCLC [3–5], and it provides various advantages, such as preservation of postoperative pulmonary function and increased tolerance for the resection of possible secondary cancers [6–8].

With the development of video-assisted thoracoscopic surgery (VATS), many surgeons have actively performed thoracoscopic pulmonary segmentectomies. The hospital stay of patients undergoing a thoracoscopic approach is shorter and their morbidity is lower than those of patients subjected to an open technique [9,10].

Total thoracoscopic pulmonary segmentectomy (TTPS) is feasible and safe, but it requires more demanding surgical skills than lobectomy [11–16]. A steep learning curve must be overcome before a surgeon achieves proficiency in TTPS because it is a complex procedure. A learning curve displays a temporal relationship between a surgeon’s mastery of a specifically assigned task and the number of cases performed [17].

Data describing the learning curve of TTPS have yet to be obtained. The authors consecutively performed 128 cases covering different types and difficulty levels. In this study, cumulative summation (CUSUM) was applied to analyze the learning curve of TTPS and present the relationship between surgical outcomes and technical progress.

Study patients

Waiving of individual patient consent was approved by the Nanjing Medical University Institutional Review Board because of the retrospective design of this study. A total of 128 consecutive TTPS were performed by a team, who has performed 300 VATS lobectomies, at the First Affiliated Hospital of Nanjing Medical University from September
2010 to December 2013. The following inclusion criteria for TTPS were considered:

1. Small peripheral nodules (diameter ≤ 2 cm) that were (i) adenocarcinoma in situ and (ii) nodules with ≥ 50% ground glass opacity on CT;
2. Poor pulmonary reserve or another major comorbidity that contraindicated lobectomy;
3. Deep indeterminate pulmonary nodules and solitary metastases that were unable to be removed by wedge resection.

**Surgical methods**

TTPS was performed under general anesthesia with single-lung ventilation. The first port (15 mm) was placed on the seventh or eighth intercostal space (ICS) on the mid-axillary line to insert a 10 mm 30° thoracoscope (Karl Storz, Germany) without CO2 insufflation. The second port (20–40 mm) was located on the fourth or fifth ICS between the anterior axillary line and the mid-clavicle line. The third port (20 mm) was positioned on the seventh or eighth ICS between the sub-scapular line and the posterior axillary line. Target pulmonary veins, arteries, and bronchus were dissected individually. Bronchoscopy was conducted when the target bronchus was difficult to identify. The intersegmental veins were preserved, and the intersegmental plane was determined on the basis of the inflated–deflated line and then separated anatomically along the intersegmental veins. The inflated–deflated interface up to the outer one-third of the pulmonary parenchyma was divided using an endo-stapler. The sufficient margins of malignant lesions (margin width ≥ 2 cm or ≥ tumor diameter) were ensured. N1 and N2 lymph nodes were sampled intraoperatively for frozen section analysis (Table S1). Lobectomy was carried out if the nodes were diseased or if the margin was insufficient. All of the primary malignant cases received hilar and mediastinal lymphadenectomy. Operative time (OT) was defined as the time from the first incising skin to the last closing port.

**CUSUM analysis**

CUSUM is the continuous accumulation of differences between the mean of all data points and an individual data point [17,18]. All of the 128 patients were sorted chronologically. The CUSUM of the first patient was the difference between the mean OT of all of the patients and the OT of the first patient. The CUSUM of the second patient was the CUSUM of the first patient added to the difference between the mean OT of all of the patients and the OT of the second patient. The CUSUM of the remaining patients were calculated in the same manner until the CUSUM of the last patient was determined. No deaths were recorded in this study. Therefore, a risk-adjusted CUSUM was unnecessary.

The row data of OT are scattered in Fig. 1. The plotted CUSUMOT was parabolic, which demonstrated a typical learning curve (Fig. 2). The curve of best fit is a second-order polynomial equation: $y = -0.3227x^2 + 38.667x + 96.173$, where $y$ represents CUSUMOT and $x$ denotes the consecutive case number. The curve yielded a high $R$ value.