Original Article

Learning curve for uniportal thoracoscopic pulmonary segmentectomy: how many procedures are required to acquire expertise?

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Background: Minimally invasive surgeries are increasingly being performed. However, few studies have evaluated the learning curve for uniportal thoracoscopic segmentectomies. Therefore, we investigated the learning curve for uniportal thoracoscopic segmentectomy in our department.

Methods: We retrospectively reviewed the clinical data of consecutive patients who underwent uniportal thoracoscopic segmentectomy at our institution between February 2019 and January 2022. Two senior surgeons [Hitoshi Igai (H.I.) and Natsumi Matsuura (N.M.)] performed all of the surgeries. H.I. introduced uniportal thoracoscopic segmentectomy in our department and supervised N.M. performing this operation. Resident surgeons participated in the operations as assistants. The learning curve for uniportal thoracoscopic segmentectomy was evaluated on the basis of operative time and cumulative sum ($CUSUM_{OT}$).

Results: The entire team, including resident surgeons, completed the learning curve by performing 60 surgeries. The learning curve consisted of three phases: initial learning (60 surgeries), accumulation of competence (16 surgeries), and acquisition of expertise (17 surgeries), respectively. The operative time, blood loss, postoperative drainage, and postoperative hospitalization time significantly improved across the phases. N.M. completed the initial learning curve faster than H.I. (16 and 29 surgeries, respectively).

Conclusions: Under supervision by an experienced surgeon, a team successfully completed the learning curve for uniportal thoracoscopic segmentectomy and achieved good perioperative outcomes, which indicates the importance of appropriate supervision for acquiring expertise for this surgery.

Keywords: Uniportal thoracoscopic segmentectomy; learning curve; cumulative sum (CUSUM)

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Introduction

The incidence of lung cancer and number of operations therefor are increasing in Japan (1). Video-assisted thoracoscopic surgery (VATS) is safe and effective for lung resection. Among them, uniportal VATS is increasingly being performed worldwide as a less invasive surgery (2-5). However, uniportal VATS requires instrumental interference, a unidirectional view, and unique technique. The time and experience required to achieve expertise in uniportal VATS are unclear.

Because of the increasing trend toward minimally invasive surgery, segmentectomy has been used as an alternative to lobectomy for early-stage non-small cell lung cancer (6-8). Moreover, a randomized controlled trial confirmed the non-inferiority of segmentectomy to lobectomy (JCOG0802/WJOG4607L) for patients with stage IA non-small cell lung cancer (tumor diameter ≤2 cm; consolidation-to-tumor ratio >0.5) (9). Therefore, segmentectomy will likely be increasingly performed in the future. Segmentectomy is a complicated procedure that requires an in-depth understanding of segmental anatomy. Therefore, uniportal segmentectomy is technically more challenging than uniportal lobectomy.

According to a consensus report from the Uniportal VATS Interest Group (UVIG) of the European Society of Thoracic Surgeons (ESTS) (10), 50 surgeries are needed to acquire expertise, and more than 40 surgeries per year are required to maintain expertise, in uniportal VATS lobectomy. By contrast, there is no consensus on the time or practice required to acquire expertise in segmentectomy. Although several studies have reported good perioperative outcomes for uniportal thoracoscopic segmentectomy (11-13), to the best of our knowledge, few have assessed the learning curve for uniportal thoracoscopic segmentectomy. It is essential to understand the learning curve for uniportal thoracoscopic segmentectomy to improve surgical skills and perioperative outcomes. Therefore, we investigated the learning curve for uniportal thoracoscopic segmentectomy in our department using the cumulative sum (CUSUM) technique. We present this article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-104/rc).

Highlight box

Key findings

- Under the supervision of an experienced surgeon, a team completed the learning curve by performing 60 surgeries and achieved good perioperative outcomes.

What is known and what is new?

- Uniportal thoracoscopic segmentectomy requires special surgical techniques and ingenuity, and takes time to master.
- There have been few studies concerning the learning curve of uniportal thoracoscopic segmentectomies. The aim of this study was to analyze the learning curve for uniportal thoracoscopic segmentectomy in our institution and the amount of experience it takes to master the procedure as a team, not just as an individual.

What is the implication, and what should change now?

- A team consisting of resident surgeons successfully completed the learning curve after 60 uniportal thoracoscopic segmentectomies. Under supervision by an experienced surgeon, a team successfully completed the learning curve for uniportal thoracoscopic segmentectomy and achieved good perioperative outcomes, which indicates the importance of appropriate supervision for acquiring expertise for this surgery.

Methods

Ethical statement

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Institutional Ethics Board of Japanese Red Cross Maebashi Hospital (dated on March 16 2022; approval No. 2021-61). The need for written informed consent was waived due to the retrospective nature of the study.

Data collection

We retrospectively analyzed the data of consecutive patients who underwent uniportal thoracoscopic segmentectomy at Japanese Red Cross Maebashi Hospital between February 2019 (when we began uniportal anatomical lung resections) and January 2022. Segmentectomy was defined as resection of a target segment and ligation of the dominant vessels and bronchi. We collected clinical data, including sex, age, American Society of Anesthesiologists (ASA) score, smoking status, forced expiratory volume in 1 second (FEV1.0), %FEV1.0, tumor location, segmentectomy type, operative time, blood loss, conversion to thoracotomy, postoperative drainage days, postoperative hospitalization duration, complications, and pathological diagnosis. Entire operative time was from the timing of initial skin incision by a scalpel to completely closure of the skin incision, which was recorded by the nurse in the operating room. Simple or complex segmentectomy was performed, depending on the surgical characteristics. Simple segmentectomy involved resection of the superior segment of the lower lobe (S6), basilar segment on each side, left upper division, and left lingual segment (14). All other procedures were classified as complex segmentectomy. Patient characteristics and perioperative outcomes between simple and complex segmentectomies were also compared.

Surgical procedure

Preoperative simulation involved three-dimensional computed tomography (3D-CT) angiography and bronchography for all patients except those with contrast allergy. The segment to be resected was identified to secure a surgical margin of at least 20 mm. The procedures were performed under general anesthesia with differential lung

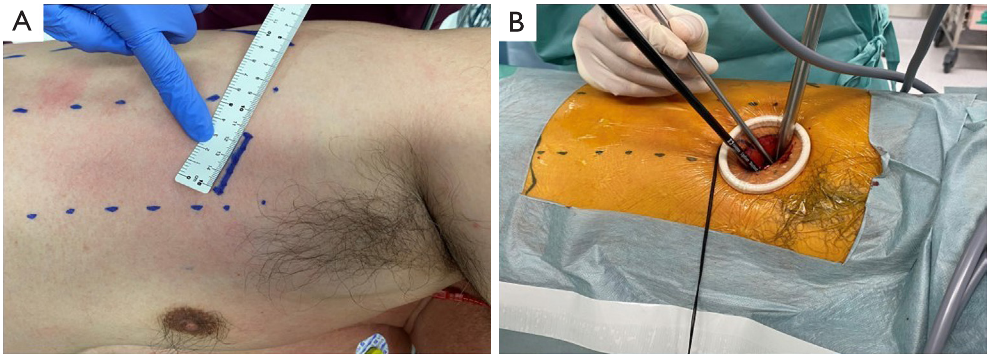

Figure 1 Right upper lobe segmentectomy. (A) A 3.5-cm skin incision in the fourth intercostal anterior axillary line. (B) An intraoperative finding demonstrating inserted several instruments including a thoracoscopy via a small skin incision.

ventilation and the patient in the lateral decubitus position. The operator and assistant stood on the ventral and dorsal sides of the patient, respectively. A 3.5–4.0-cm skin incision was made in the fifth intercostal anterior axillary line. A skin incision was made in the fourth intercostal anterior axillary line for right upper lobe segmentectomy (*Figure 1A*). An XS Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA, USA) was applied to the wound. A 10-mm 30º thoracoscope (Visera Elite LI Olympus CLV-S200-IR; Olympus Deutschland GmbH, Hamburg, Germany) was fixed on the dorsal side of the wound margin (*Figure 1B*). The vessels and bronchi were transected using an automatic stapler. However, small vessels were occasionally ligated proximally using a 3-0 silk and divided distally using an energy device. Although an inflation-deflation technique was used for intersegmental identification; infrared thoracoscopic observation with intravenous administration of indocyanine green has been performed to identify the intersegmental plane since May 2020. The intersegmental planes were divided using staplers. A chest drain (24-Fr double-lumen trocar) was finally placed in the ventral side of the wound. Intentional segmentectomy was performed for only pure or part-solid ground-glass nodules with solid component ≤1 cm in size with hilar lymph node sampling. We did not perform systemic lymphadenectomy in intentional segmentectomy. In addition, unintentional segmentectomy was performed as a passive limited surgery in patients with low pulmonary function or poor cardiopulmonary function. Wedge resection is usually performed for metastatic lung tumors, but depending on the location of the tumor, a segmentectomy may be chosen to secure margins. In case with benign disease, the surgical procedure is selected by the same criteria as pulmonary metastasis. All cases with benign disease received segmentectomy based on suspicious of malignant disease. In unintentional segmentectomy and segmentectomy for pulmonary metastasis or benign disease, hilar lymph node sampling was not performed.

A senior surgeon [Hitoshi Igai (H.I.)] began performing uniportal thoracoscopic anatomical lung resection in our department. After H.I. had performed 40 uniportal thoracoscopic anatomical lung resections, including 17 segmentectomies, another senior surgeon [Natsumi Matsuura (N.M.)] started performing the surgery. Any operation in this study was performed by H.I. or N.M. Resident surgeons participated in the operations as assistants. They mainly manipulated a thoracoscope and retracted lung using a forceps. The operations were supervised by H.I. For instance, when N.M. encountered difficult part to treat, H.I. advised how to overcome it. Otherwise, H.I. alternatively defeated the difficult part. H.I. and N.M. performed more than 500 mulitiportal thoracoscopic anatomical lung resections before performing uniportal thoracoscopic anatomical lung resections.

Postoperative management

The chest drain was removed once a lack of active bleeding and air leakage was confirmed. The patients were discharged if the chest X-ray performed on the day after chest drain removal was normal. Postoperative complications were evaluated using the Clavien-Dindo classification (15).

Statistical analysis

The CUSUM technique was used for the quantitative assessment of the learning curve. The CUSUM method is used to determine a gradual change in quantity over time, and was adopted by the medical profession in 1968 to analyze the learning curve for surgical procedures (16,17). First, all patients were arranged in chronological order and the average operative time was calculated. The CUSUM of the first data point is the difference between the first point and the average of all points; the CUSUM of the second data point is the difference between the second point and the average of all points. After calculating the CUSUMs for all data points, the remaining data were algebraically added to the previous sum. In the present study, the learning curve was evaluated using operative time and its CUSUM ($CUSUM_{OT}$). We assessed the curve of best fit for detecting a change in the slope of the CUSUM learning curve. A positive and negative slope indicated cases with above- and below-average operative times, respectively. The number of cases required was calculated from the inflection point of the curve of the line representing the best fit for the plot.

Fisher's exact test was used to compare categorical variables. The Kruskal-Wallis analysis or the *t*-test was used for comparisons of continuous variables and the Steel-Dwass analysis for multiple comparison post-hoc test. P<0.05 was considered statistically significant. The statistical analyses were performed using EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), a graphical user interface for R (R Foundation for Statistical Computing, Vienna, Austria). Specifically, a modified version of R commander designed to add statistical functions was used for the analysis.

Results

Table 1 presents the patient characteristics and perioperative outcomes. Ninety-three consecutive patients were included in this study, which was comprised of 46 males and 47 females with a mean age of 69 years. In total, 54 patients (58.1%) had a smoking history (mean of 43 pack-years). During the study period, 41 simple, and 52 complex, segmentectomies were performed. The segmentectomy regions included S1, S2, S3, S1+3, S2+6, S6, S8, S7+8, S7+8+9, S9+10, S10, and S7+8+9+10 on the right side, and S1+2, S1+2+3, S3, S3+4+5, S4+5, S6, S8, S9+10, and S8+9+10 on the left side (*Tables 2,3*). The preoperative FEV1.0 and %FEV1.0 were 2.1 L [standard deviation (SD): 0.6] and 88.8% (SD: 19.9%), respectively. In total, 61 and 11 patients had primary and metastatic lung cancer, respectively. In cases of primary lung cancer, there were cases with visceral pleural invasion or tumor diameter that reached pathological stage 1B or above, but none of the cases were upstaged due to lymph node metastasis.

In all patients (n=93), the mean operative time was 133 min (SD: 42) and the mean blood loss was 30 mL (SD: 67). The operative times of all patients were plotted in chronological order (*Figure 2*), but no clear change or trend was observed. By contrast, the $CUSUM_{OT}$ of the learning curve demonstrated a downward slope after reaching its peak at 60 cases (*Figure 3*). The learning curve could be divided into three phases according to the slope of the best fit curve. Phases 1–3 included initial learning (the ascending slope of the curve: 60 cases), competence accumulation (the plateau of the curve:16 cases), and acquisition of expertise (the descending slope of the curve: 17 cases), respectively.

Table 1 compares patient characteristics and perioperative outcomes among the three phases. There were no significant differences in patient characteristics, tumor location, or segmentectomy type among the three phases. Perioperative outcomes, such as operative time, blood loss, conversion to thoracotomy, and complications, improved over time. Operative time decreased as phase progressed, but the difference was not significant (P=0.082). Blood loss (P=0.033), the postoperative drainage period (P<0.001), and the length of hospital stay (P=0.008) were all significantly different between the three groups. The Steel-Dwass test showed the significant difference between phase 1 and phase 3 in terms of blood loss (P=0.038), the postoperative drainage period (P=0.002), and the length of hospital stay (P=0.016). Postoperative complications occurred in 5 patients (5.3%), including atrial fibrillation (n=1), prolonged air leakage (n=1), delayed pneumothorax (n=1), and hypoxemia (n=2). All complications occurred during phase 1.

The $CUSUM_{OT}$ of the learning curves of H.I. and N.M. are presented in *Figure 4*. H.I. completed the initial learning curve (phase 1) after 29 cases and competence accumulation (phase 2) after an additional 20 cases, and finally acquired expertise (phase 3). In comparison, N.M. completed the initial learning curve (phase 1) after 16 cases and competence accumulation (phase 2) after additional 8 cases, and finally acquired expertise (phase 3) (*Figure 4A*: H.I., *Figure 4B*: N.M.).

Table 4 compares patient characteristics and perioperative outcomes between simple and complex segmentectomies. There were no significant differences between the two groups other than blood loss. The $CUSUM_{OT}$ of learning curves for simple and complex segmentectomies are presented

Table 1 Patient characteristics and perioperative outcomes across phases

Characteristics	All (n=93)	Phase I (n=60)	Phase II (n=16)	Phase III (n=17)	P
Sex (male)	46 (49.5)	31 (51.6)	6 (37.5)	9 (52.9)	0.597
Age (years)	70 (66 to 78)	70 (66 to 78)	71 (65 to 75)	74 (65 to 78)	0.851
ASA score	2 (2 to 2)	2 (2 to 2)	2 (2 to 2)	2 (2 to 3)	0.491
Smoking history (yes)	54 (58.1)	35 (58.3)	10 (62.5)	9 (52.9)	0.821
Pack-years	15 (0 to 45)	20 (0 to 45)	14 (0 to 32)	3 (0 to 46)	0.808
Preoperative pulmonary function test					
FEV1 (L)	1.9 (1.6 to 2.4)	2.0 (1.7 to 2.4)	1.9 (1.7 to 2.5)	1.8 (1.3 to 2.2)	0.396
FEV1 Pred (%)	91 (75 to 103)	91 (76 to 104)	100 (81 to 108)	80 (73 to 91)	0.263
Tumor location					0.596
RUL	29 (31.2)	19 (31.7)	4 (25.0)	6 (35.3)	
RLL	25 (26.9)	19 (31.7)	2 (12.5)	4 (23.5)	
LUL	25 (26.9)	15 (25.0)	6 (37.5)	4 (23.5)	
LLL	14 (15.0)	7 (11.6)	4 (25.0)	3 (17.7)	
Segmentectomy type					0.685
Simple	41 (44.1)	27 (45.0)	8 (50.0)	6 (35.3)	
Complex	52 (55.9)	33 (55.0)	8 (50.0)	11 (64.7)	
Operation time, min	130 (105 to 150)	140 (105 to 166)	123 (110 to 136)	120 (95 to 135)	0.082
Blood loss, mL	0 (0 to 50)	0 (0 to 50)	0 (0 to 31)	0 (0 to 0)	0.033
Conversion to thoracotomy	3 (3.2)	3 (5.0)	0 (0.0)	0 (0.0)	1.000
Due to bleeding	2 (2.2)	2 (3.3)	0 (0.0)	0 (0.0)	
Postoperative drainage, days	1 (1 to 1)	1 (1 to 2)	1 (1 to 1)	1 (0 to 1)	<0.001
Postoperative hospitalization, days	2 (2 to 4)	3 (2 to 4)	2 (2 to 3)	2 (2 to 2)	0.008
Postoperative complications	5 (5.4)	5 (8.3)	0 (0.0)	0 (0.0)	0.511
Pathological diagnosis					0.138
Primary lung cancer	66 (71.0)	46 (76.7)	8 (50.0)	12 (70.6)	
Metastatic lung tumor	11 (11.8)	4 (6.6)	4 (25.0)	3 (17.6)	
Benign lesion	16 (17.2)	10 (16.7)	4 (25.0)	2 (11.8)	
Pathological stage					–
0	22 (33.3)	18 (39.1)	0 (0.0)	4 (33.3)	
1A1/1A2/1A3	17/15/4 (54.5)	10/11/2 (50.0)	4/2/1 (87.5)	3/2/1 (50.0)	
1B	3 (4.5)	2 (4.4)	1 (12.5)	0 (0.0)	
2/3/4	2/0/3 (7.6)	1/0/2 (6.5)	0/0/0	1/0/1 (16.7)	

Data are shown as n (%) or median (IQR). ASA, American Society of Anesthesiologists; FEV1 Pred, predicted forced expiratory volume in 1 second; RUL, right upper lobe; RLL, right lower lobe; LUL, left upper lobe; LLL left lower lobe; IQR, interquartile range.

Table 2 Locations of complex segmentectomy

Location	Complex segmentectomy (n=52), n (%)
Right side	
Upper lobe	29 (55.8)
S1	5 (9.6)
S2	12 (23.1)
S3	8 (15.4)
S1+3	3 (5.8)
S2+6	1 (1.9)
Lower lobe	10 (19.2)
S7+8	1 (1.9)
S7+8+9	1 (1.9)
S8	1 (1.9)
S9+10	6 (11.6)
S10	1 (1.9)
Left side	
Upper lobe	8 (15.3)
S1+2	3 (5.8)
S3	3 (5.8)
S3+4+5	2 (3.8)
Lower lobe	5 (9.6)
S8	4 (7.7)
S9+10	1 (1.9)

in *Figure 5*. The initial learning curve was completed after 31 cases for simple segmentectomy (*Figure 5A*) and 30 cases for complex segmentectomy (*Figure 5B*).

Discussion

CUSUM has mainly been used for quality control of industrial products and analysis of surgical learning curves and clinical data (16,17). CUSUM allows rapid and powerful assessment of changes in means or slopes of trends for data collected at regular intervals. CUSUM has previously been used to evaluate the learning curves for robotic-assisted and laparoscopic surgeries (18,19). In the present study, we assessed the learning curve for uniportal thoracoscopic segmentectomy using the CUSUM technique, for individual surgeons and teams, in terms of the number of cases required to acquire expertise.

Table 3 Locations of simple segmentectomy

Location	Simple segmentectomy (n=41), n (%)
Right side	
Upper lobe	0 (0.0)
Lower lobe	15 (36.6)
S6	10 (24.4)
Basal segment	5 (12.2)
Left side	
Upper lobe	17 (41.4)
Upper divisional segment	14 (34.1)
Lingual segment	3 (7.3)
Lower lobe	9 (22.0)
S6	6 (14.7)
Basal segment	3 (7.3)

A few studies have evaluated the learning curve for port-access thoracoscopic anatomical lung segmentectomy (20-24). Dimitrovska *et al.* (21) reported that the first phase of the learning curve for two-port VATS segmentectomy was completed after 27 surgeries, and the surgeons became proficient after 57 surgeries. Chen *et al.* (24) demonstrated that surgeons completed initial learning curve after performing 20–29 surgeries, and competence accumulation after performing 58–63 surgeries. In the present study, the first phase of the learning curve was completed after 60 surgeries, and the technique was mastered after 76 surgeries. Unlike previous studies, in which the surgeries were performed by a single surgeon, we evaluated the learning curve for two senior surgeons with different levels of experience, which focused on the learning curve as a team. We considered the assistant's camera work and lung deployment are also essential for the smooth progression of the operation in uniportal VATS segmentectomy. Our results suggested that, although the uniportal thoracoscopic segmentectomies in our department were performed by different surgeons, the quality of surgery improved over time due to supervision by a senior surgeon (H.I.). The UVIG of ESTS suggests that surgeons should be supervised when they begin performing uniportal VATS lobectomies (10), which suggests that supervision may also be useful for uniportal VATS segmentectomy.

We analyzed the $CUSUM_{OT}$ of the learning curves

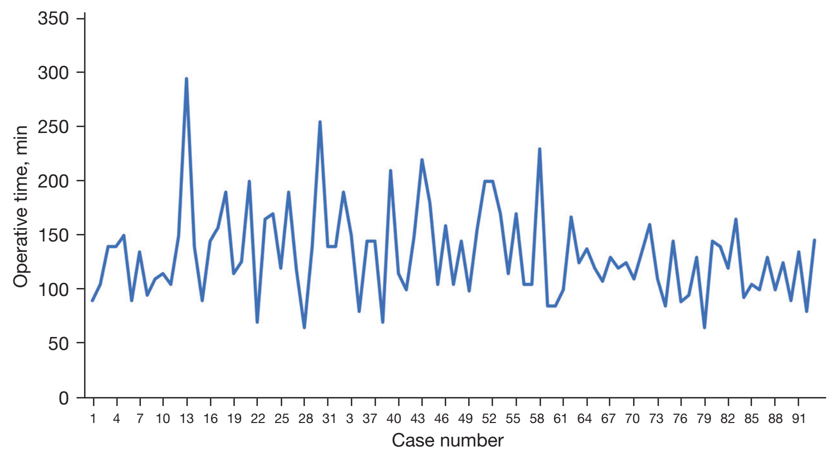

Figure 2 Operative time of surgeries in chronological order.

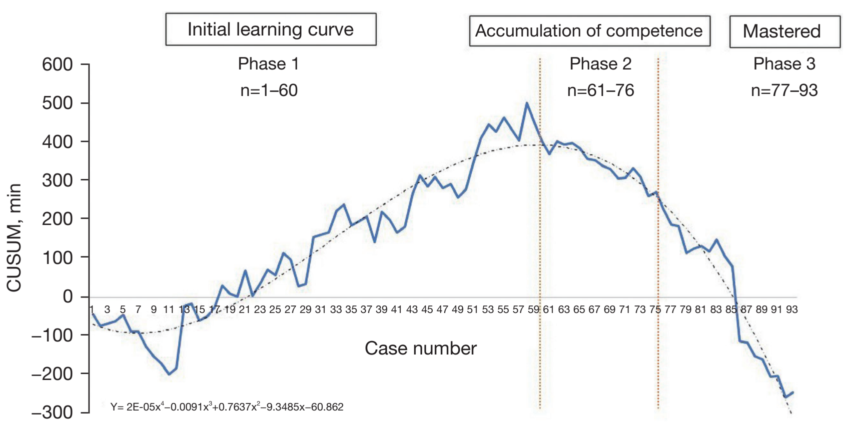

Figure 3 CUSUM$_{OT}$ of learning curve. Dotted line indicates the slope of the best fit curve. The curve is divided into three phases. CUSUM, cumulative sum; OT, operative time.

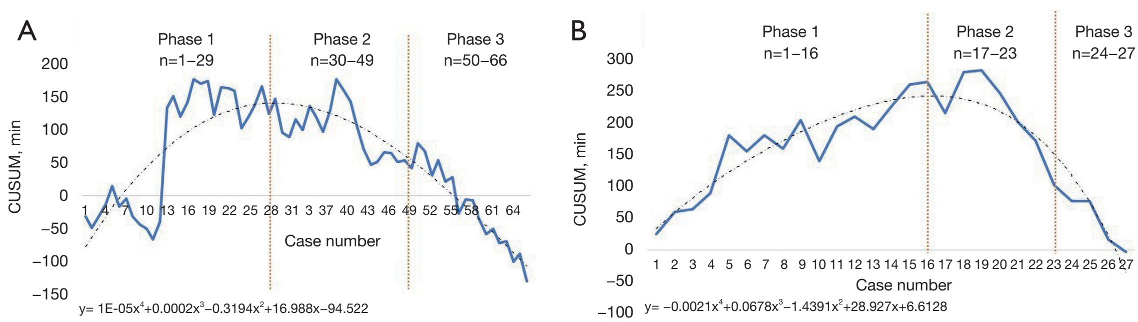

Figure 4 CUSUM$_{OT}$ of learning curves of two senior surgeons. (A) H.I.; (B) N.M. CUSUM, cumulative sum; OT, operative time.

Table 4 Comparison of patient characteristics and perioperative outcomes between simple and complex segmentectomies

Characteristics	Simple (n=41)	Complex (n=52)	P
Sex (male)	20 (48.8)	26 (50.0)	1
Age (years)	71.1±9.0	68.7±14.0	0.334
ASA score	2	2	0.794
Smoking history			
Yes	27 (65.9)	27 (51.9)	0.388
Pack-years	29±31	23±28	0.299
Preoperative pulmonary function test			
FEV1 (L)	2.0±0.6	2.1±0.7	0.94
FEV1 Pred (%)	89.3±19.5	88.4±20.6	0.84
Tumor location			<0.001
RUL	0 (0.0)	29 (55.8)	
RLL	15 (36.6)	10 (19.2)	
LUL	17 (41.5)	8 (15.4)	
LLL	9 (21.9)	5 (9.6)	
Operative time, min	133±50	133±35	0.943
Blood loss, mL	51±93	14±29	0.008
Conversion to thoracotomy	3 (7.3)	0 (0.0)	0.082
Due to bleeding	2 (4.9)	0 (0.0)	
Postoperative drainage (days)	1.3±1.0	1.3±1.1	0.964
Postoperative hospitalization (days)	3.5±2.4	2.7±1.3	0.059
Postoperative complications	2 (4.9)	3 (5.8)	1
Pathological diagnosis			0.945
Primary lung cancer	30 (73.2)	36 (69.2)	
Metastatic lung tumor	4 (9.8)	7 (13.5)	
Benign lesion	7 (17.0)	9 (17.3)	

Data are shown as n (%) or score or mean ± SD. ASA, American Society of Anesthesiologists; FEV1 Pred, predicted forced expiratory volume in 1 second; RUL, right upper lobe; RLL, right lower lobe; LUL, left upper lobe; LLL left lower lobe; SD, standard deviation.

of H.I. and N.M. Although H.I. completed the initial learning curve after 29 surgeries, N.M. began performing the surgeries later and completed the initial learning curve after 16 surgeries. This difference may be related to the effectiveness of supervision of N.M. by H.I., who had significant experience in performing uniportal VATS segmentectomy. The supervision by H.I. enabled N.M. to overcome the technical difficulties of the operation, which allowed faster completion of the second and third phases of the learning curve.

The $CUSUM_{OT}$ of the learning curve was divided into three phases: initial learning curve, accumulation of competence, and mastery. After completing the initial learning curve and a short period of competence accumulation, mastery was achieved. The operative time was significantly shortened, and the perioperative outcomes, such as blood loss, conversion to thoracotomy, and postoperative hospital stay duration, were significantly improved. Moreover, conversion to thoracotomy or complications happened only in the initial learning curve phase although it was statistically significant. Previous studies have also reported that the operative time, blood loss (21-24),

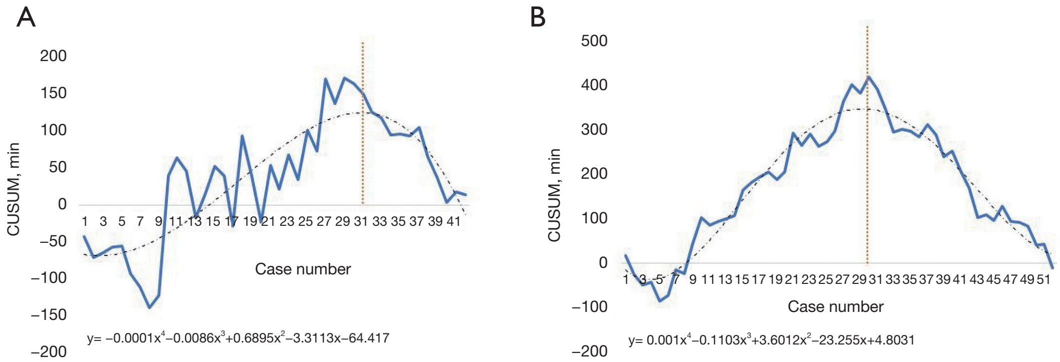

Figure 5 $CUSUM_{OT}$ of learning curves for simple and complex segmentectomies. (A) Simple segmentectomy. (B) Complex segmentectomy. CUSUM, cumulative sum; OT, operative time.

postoperative hospital stay duration (23), and complications (24) are improved after the surgeon acquires expertise. By learning the techniques involved in uniportal VATS, such as instrument interference and limiting the insertion angle of staplers when dissecting intersegmental planes, blood loss and air leakage were reduced, and postoperative drainage and hospital stay durations were shortened.

In the present study, we analyzed the difference in learning curves between simple and complex segmentectomies. The surgeries were initiated at the same time with no restrictions on simple or complex segmentectomies; the cases of simple and complex segmentectomies were uniformly distributed throughout the study period. Several previous studies have reported that complex segmentectomies have longer operative times (25) and more frequent adverse events (26) compared to simple segmentectomies. In the present study, the initial learning curve was completed after 31 surgeries for simple segmentectomy and 30 surgeries for complex segmentectomy; these numbers were not significantly different. Our team previously demonstrated the equivalent perioperative outcomes between thoracoscopic simple and complex segmentectomies via multiport (27). Our results suggest that both simple and complex segmentectomies can be similarly mastered even via uniport and provide good perioperative outcomes.

There were some important limitations to this study. First, it used a retrospective, single-center design. Moreover, the number of patients included was small (especially, in phase 2 and 3). Therefore, we did not adjust patient backgrounds when perioperative outcomes were compared between the phases. Second, the learning curve changes were affected by the surgical experience of surgeons. Because we focused on data from two senior surgeons, it is unclear how the learning curves of resident, or inexperienced, surgeons would progress. Future studies should also analyze the learning curves of resident surgeons. Third, we did not analyze the long-term prognosis or local recurrence rate after surgery performed for malignant diseases.

Finally, the limitations of using CUSUM analysis as a surgical learning curve have been pointed out (28), and further study is needed on better methods, including the fundamental question of whether it is correct to measure surgical proficiency in terms of operating time.

Conclusions

In conclusion, a team consisting of resident surgeons successfully completed the learning curve after 60 uniportal thoracoscopic segmentectomies. After completing the initial learning curve and a brief accumulation of competence phase, mastery was achieved. The operative time was reduced, and other perioperative outcomes were improved, in each subsequent phase of the learning curve. Two senior surgeons completed the learning curve after 16 and 29 surgeries, respectively. Our results suggest that appropriate supervision by an experienced surgeon may reduce the time and number of cases required to complete the learning curve for uniportal thoracoscopic segmentectomy. Finally, there was no difference in the learning curves between simple and complex segmentectomies, although complex segmentectomy was considered more technically difficult than simple segmentectomy.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-104/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-104/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and approved by the Institutional Ethics Board of Japanese Red Cross Maebashi Hospital (dated on March 16 2022; approval No. 2021-61). The need for written informed consent was waived due to the retrospective nature of the study.

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