Original Article

Supervision by an experienced surgeon can reduce the learning curve of uniportal thoracoscopic lobectomy

Hitoshi Igai^, Natsumi Matsuura, Kazuki Numajiri, Fumi Ohsawa, Mitsuhiro Kamiyoshihara

Department of General Thoracic Surgery, Japanese Red Cross Maebashi Hospital, Maebashi, Japan

Contributions: (I) Conception and design: H Igai; (II) Administrative support: H Igai; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: H Igai; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Hitoshi Igai. Department of General Thoracic Surgery, Japanese Red Cross Maebashi Hospital, 389-1 Asakura, Maebashi City, Gunma 371-0811, Japan. Email: hitoshiigai@gmail.com.

Background: This retrospective study was performed to investigate the learning curve of uniportal thoracoscopic lobectomy with ND2a-1 or greater lymphadenectomy for two senior surgeons, and to evaluate how supervision affected the learning curve.

Methods: Between February 2019 and January 2022, 140 patients with primary lung cancer underwent uniportal thoracoscopic lobectomy with ND2a-1 or greater lymphadenectomy in our department. Two senior surgeons (HI and NM) performed most of the operations, with junior surgeons performing the rest. HI initiated this surgical method in our department and supervised all operations performed by other surgeons. Patient characteristics and perioperative outcomes were reviewed, and the learning curve was evaluated based on operative time and the cumulative sum method ($CUSUM_{OT}$).

Results: No significant differences were observed in patient characteristics or perioperative outcomes between groups. Three distinct learning curve phases were identified for each senior surgeon: HI, cases 1–21, cases 22–40, cases 41–71; NM cases 1–16, cases 17–30, cases 31–49. For HI, the rate of conversion to thoracotomy was significantly higher in the initial phase (14.3%, P=0.04) although other perioperative outcomes were equivalent between phases. For NM, while the duration of postoperative drainage was significantly shorter in phase 2 and phase 3 (P=0.026), other perioperative outcomes, including conversion rate (5.3–7.1%), were equivalent between phases.

Conclusions: Supervision by an experienced surgeon was important for avoiding conversion to thoracotomy during the initial period, and facilitated the surgeon rapidly gaining proficiency with the surgical method.

Keywords: Learning curve; uniportal approach; lobectomy

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Introduction

Rocco *et al.* first reported wedge resection using the uniportal approach in 2004 (1), followed by the first report of uniportal thoracoscopic major pulmonary resection described by Gonzalez *et al.* in 2011 (2). This approach involves a single skin incision, which is considered less invasive than the multiportal approach, and has been gaining worldwide acceptance. Several reports have suggested that a uniportal thoracoscopic approach can not only result in fewer skin incisions, but also provide additional better

^ ORCID: 0000-0002-5916-8209.

perioperative outcomes in major pulmonary resections, including a significantly shorter operative time, reduced intraoperative bleeding, and shorter postoperative drainage or hospitalization time, in comparison to multiportal approaches (3-5).

However, the uniportal thoracoscopic approach is more technically difficult compared to the multiportal approach due to the simultaneous insertion of surgical instruments including the thoracoscope via a small single skin incision. These surgical instruments can interfere with each other during the surgery, so thoracic surgeons may hesitate to adopt this method due to the technical difficulties, with concerns regarding safety and feasibility. A few authors have reported the learning curve of uniportal thoracoscopic major pulmonary resection, to provide guidance for overcoming such hesitancy (6-10). However, most of these reports only described the learning curve for a single surgeon. Therefore, we conducted a retrospective review. One of the authors (HI) initiated uniportal thoracoscopic major pulmonary resection including lobectomy and segmentectomy in our department. After HI had gained experience with a sufficient number of cases, another surgeon (NM) began to perform this operation under the supervision of HI. We present the following article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-22-739/rc).

Methods

This retrospective study was performed to investigate the learning curve of uniportal thoracoscopic lobectomy with ND2a-1 or greater lymphadenectomy for two senior surgeons (HI and NM) in our department, and to evaluate how supervision affected the learning curve. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study protocol was approved by institutional ethics board of Japanese Red Cross Maebashi Hospital (approval No. 2022-05) and the need for individual consent for this retrospective analysis was waived.

Our department began uniportal thoracoscopic major pulmonary resection including lobectomy and segmentectomy in February 2019. The uniportal approach was initially adopted only for cT1N0 cases or metastatic lung cancer to ensure the safety of the operation; this was also part of our strategy to allow the surgical team to become familiar with this less invasive procedure. A multiportal approach was adopted for all other major pulmonary resections during this introductory period. All of the initial 30 operations were performed by HI. In December 2019, after uniportal thoracoscopic major pulmonary resection had been performed in 30 cases, the uniportal approach was adopted for most patients with primary lung cancer. The exclusion criteria were as follows: requiring angioplasty and/or bronchoplasty, necessary to reconstruct the chest wall, invasion into intrathoracic great vessels, or tumor measuring ≥7 cm. After HI had performed uniportal thoracoscopic major pulmonary resection in 40 cases, NM and junior surgeons began to perform this operation under supervision by HI. Both HI and NM had performed more than 500 thoracoscopic major pulmonary resections via a multiportal approach before starting the uniportal approach. Although the experience varied among the junior surgeons, any of them had less than 50 thoracoscopic major pulmonary resections via a multiportal approach. In addition, when the junior surgeons encountered the technically difficult part, the experienced surgeon (HI) alternatively defeated it.

Between February 2019 and January 2022, 259 patients underwent thoracoscopic major pulmonary resection in our department. Among them, 140 patients with lung cancer undergoing uniportal thoracoscopic lobectomy with ND2a-1 or greater lymphadenectomy were enrolled in this study. *Figure 1* presents the patient enrollment process. The clinical data analyzed for each case included age, sex, American Society of Anesthesiologists (ASA) score, smoking index (pack-years), forced expiratory volume in one second (FEV1.0), %FEV1.0, tumor localization, histology, clinical stage, operative time, intraoperative blood loss, rate of significant vessel injury, rate of conversion to thoracotomy, duration of postoperative drainage, postoperative hospitalization time, morbidity (Clavien-Dindo grade ≥ III), rate of readmission within 30 days after the operation, and

Highlight box

Key findings
- Supervision by an experienced surgeon facilitated the learning curve of operative time in uVATS lobectomy.

What is known and what is new?
- Supervision by an experienced surgeon helps surgeons acquire proficiency with the surgical method in uVATS lobectomy.

What is the implication, and what should change now?
- uVATS lobectomy should be introduced under supervision by an experienced surgeon to reach the proficiency period rapidly.

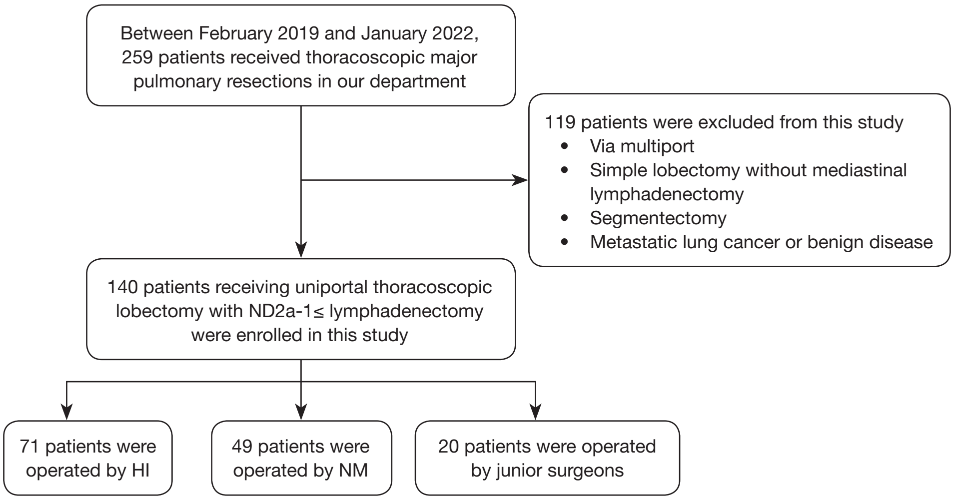

Figure 1 Patient enrollment process.

30- and 90-day postoperative mortality rates.

Evaluation of the learning curve

The cumulative sum (CUSUM) method was used for quantitative assessment of the learning curve; this is the cumulative sum of differences between the individual data points and the mean of all data points. The CUSUM method enables the detection of small changes in performance measures that may be undetectable using other measures (11,12). The CUSUM for the variables of interest in the first patients was the difference between the value for the first patient and the mean for all patients. The CUSUM for the second patient was the previous patient's CUSUM added to the difference obtained for the second patient. This recursive process continued until the CUSUM for the last patient was calculated as zero. In this study, the learning curve was evaluated using operative time and CUSUM ($CUSUM_{OT}$). We assessed the curve of best fit for detecting the change in slope of the CUSUM learning curve. In this method, positive and negative slopes indicated a series of cases with above-average and below-average operative time, respectively. The cases required for learning were calculated from the inflection point of the curve of the line representing the best fit for the plot.

Surgical procedures

Uniportal thoracoscopic lobectomy was performed with the patient in the lateral decubitus position under general anesthesia and receiving single-lung ventilation. A single 3.5–4-cm skin incision was made on the anterior axillary line of the 4th or 5th intercostal space, and initially covered using an extra-small wound retractor (Alexis Wound Retractor; Applied Medical, Rancho Santa Margarita, CA, USA). *Figure 2* presents a single skin incision (*Figure 2A*), an operative finding (*Figure 2B*) and specific surgical instruments (*Figure 2C*) in uniportal thoracoscopic surgery. Dominant vessels, including the pulmonary artery and vein, were exposed sufficiently and then divided, mainly using endovascular staplers. Small branches of these vessels were divided using an energy device after proximal ligation with silk sutures. The dominant bronchus was also divided using a stapler. Interlobar fissures were mainly divided using staplers or sometimes an energy device after ligation with silk sutures. The specimen was finally removed from the thorax after placing it in a plastic bag. ND2a-1 or greater lymphadenectomy was then performed; ND2a-1 consisted of lymphadenectomy with selective mediastinal dissection, while ND2a-2 consisted of radical mediastinal dissection (13). At the end of the operation, a chest drainage tube was placed in the thorax.

Postoperative treatment

The chest drainage tube was removed after confirming that there was no active bleeding and no air leakage. Patients were discharged if the chest X-ray taken the day after removal of the chest drain did not show any problems. Postoperative complications were evaluated using the

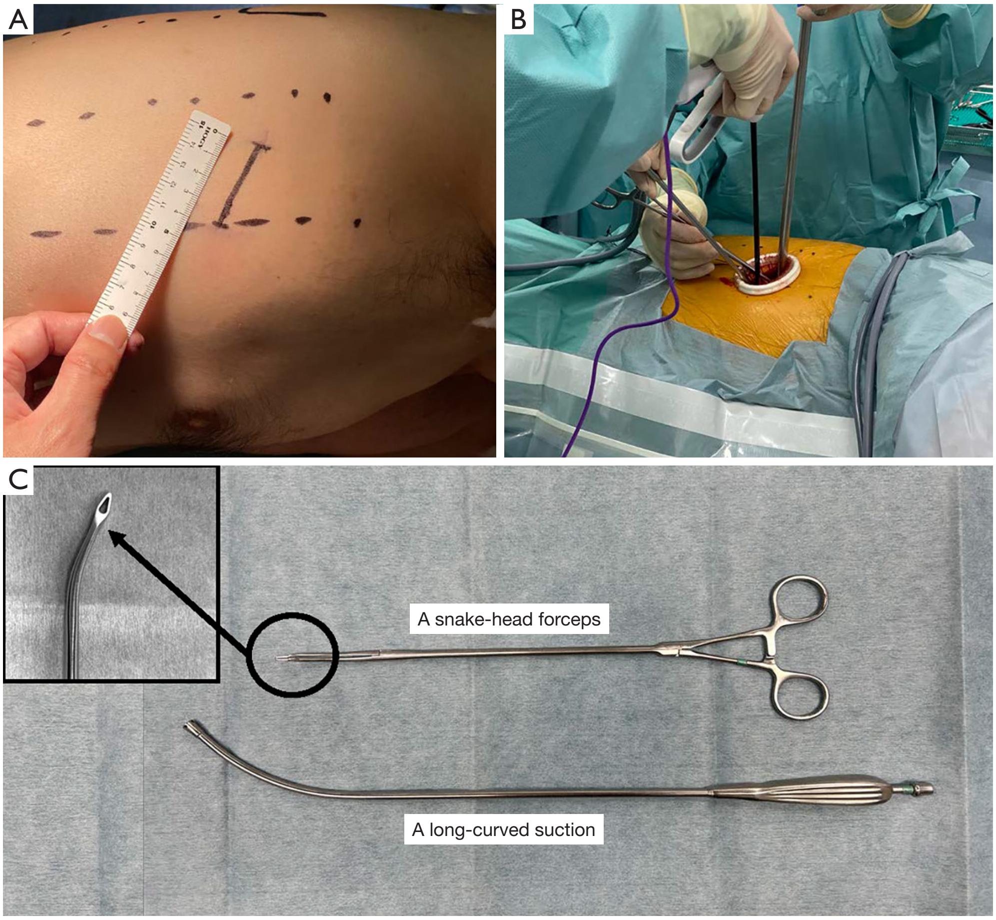

Figure 2 Intraoperative photos and surgical instruments in our uniportal thoracoscopic lobectomy. (A) Single skin incision 3.5–4 cm in length; (B) operative findings; (C) a snake-head forceps to grasp tissue and a long-curved suction to retract tissue was frequently used in our uniportal thoracoscopic lobectomy.

Clavien-Dindo classification (14).

Statistical analysis

The independent *t* test, Mann-Whitney U test, or Fisher's exact test was used to assess patient characteristics and perioperative results between the phases based on the inflection point of $CUSUM_{OT}$ or between operation groups as appropriate. Differences were considered significant at $P<0.05$. All calculations and statistical analyses were performed using the EZR graphical user interface for R (Saitama Medical Centre, Jichi Medical University, Saitama, Japan).

Results

Patient characteristics and perioperative outcomes

Table 1 lists patient characteristics and perioperative outcomes. We did not have any converted cases from uniport to multiport.

Comparison of patient characteristics and perioperative outcomes among surgeons

Table 2 compares patient characteristics and perioperative outcomes among the three groups of surgeons. No significant differences were observed in any variables,

Table 1 Patient characteristics and perioperative results in all cases (n=140)

Variables	Results
Age (years), mean ± SD [range]	72±10 [39–92]
Sex, n (%)	
Female	61 (43.6)
Male	79 (56.4)
ASA score, median [IQR]	2 [1–3]
Smoking index (pack-years), mean ± SD [range]	25±27 [0–144]
FEV1.0 (mL), mean ± SD [range]	2,228±635 [900–5,170]
%FEV1.0 (%), mean ± SD [range]	95±18 [51–136]
Tumor location, n (%)	
RUL	45 (32.1)
RML	10 (7.1)
RLL	43 (30.7)
LUL	18 (12.9)
LLL	24 (17.1)
Histology, n (%)	
Adenocarcinoma	100 (71.4)
Squamous cell carcinoma	27 (19.3)
Others	13 (9.3)
c-Stage, n (%)	
0	1 (0.7)
I	113 (80.7)
II	18 (12.9)
III	8 (5.7)
IV	0 (0.0)
Operative time (min), mean ± SD [range]	152±41 [70–280]
Blood loss (g), mean ± SD [range]	45±79 [0–600]
Significant vessel injury, n (%)	6 (4.3)
Conversion to thoracotomy, n (%)	7 (5.0)
Duration of postoperative drainage (days), mean ± SD [range]	1.7±1.6 [1–10]
Postoperative hospitalization time (days), mean ± SD [range]	5.4±17 [2–189]
Morbidity (C-D classification grade ≥3), n (%)	21 (15.0)
Readmission within 30 days after the operation, n (%)	10 (7.1)
30-day postoperative mortality, n (%)	0 (0.0)
90-day postoperative mortality, n (%)	0 (0.0)

ASA, American Society of Anesthesiologists; FEV, forced expiratory volume; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; C-D classification, Clavien-Dindo classification; SD, standard deviation; IQR, interquartile range.

including patient characteristics and perioperative outcomes, among the three groups.

Learning curves

Figure 3 presents raw data of the operative times and the $CUSUM_{OT}$ learning curve in all cases. The $CUSUM_{OT}$ learning curve in all cases was best modeled as a third-order polynomial with the CUSUM equation in minutes equal to $0.0006 \times \text{case number}^3 - 0.1305 \times \text{case number}^2 + 5.9862 \times \text{case number} - 18.192$. A convex upward function was observed until the 105th case, after which a convex downward function was observed, indicating that operative time was significantly longer after the case.

Figure 4 presents the $CUSUM_{OT}$ learning curves of each senior surgeon (HI and NM). The $CUSUM_{OT}$ learning curve in cases treated by HI was best modeled as a second-order polynomial with the CUSUM equation in minutes equal to $-0.0416 \times \text{case number}^2 + 1.8168 \times \text{case number} + 96.922$. HI completed the initial learning curve (phase 1) after 21 cases, showed competence accumulation (phase 2) after an additional 19 cases, and finally reached mastery (phase 3) (*Figure 4A*). The $CUSUM_{OT}$ learning curve in cases treated by NM was best modeled as a second-order polynomial with the CUSUM equation in minutes equal to $-0.23 \times \text{case number}^2 + 7.5826 \times \text{case number} + 92.853$. NM completed the initial learning curve (phase 1) after 16 cases, showed competence accumulation (phase 2) after an additional 14 cases, and finally reached mastery (phase 3) (*Figure 4B*). The case number where the trend changed was decided as the inflection point of the operative time.

Interphase comparison of patient characteristics and perioperative results

Table 3 compares patient characteristics and perioperative outcomes between the phases in operations performed by HI. With the exception of type of histology, patient characteristics did not differ significantly between phases. Although the operative time decreased gradually, it did not differ significantly between phases. The rate of conversion to thoracotomy was significantly higher in the initial phase (P=0.04); 14.3% of the patients underwent conversion to thoracotomy in the initial phase, while there were no cases of conversion in the transition or proficient phases. Other perioperative outcomes were equivalent between the phases.

Table 4 compares patient characteristics and perioperative outcomes between the phases in operations performed

Table 2 Comparison of patient characteristics and perioperative results between groups

Variables	Senior surgeon 1 (HI, n=71)	Senior surgeon 2 (NM, n=49)	Junior surgeons (n=20)	P value
Age (years)	72±10	71±10	73±12	0.6
Sex				0.65
Female	32 (45.1)	19 (38.8)	10 (50.0)	
Male	39 (54.9)	30 (61.2)	10 (50.0)	
ASA score, median [IQR]	2 [1–3]	2 [1–3]	2 [1–3]	0.2
Smoking index (pack-years)	25±26	22±22	33±43	0.38
FEV1.0 (mL)	2,195±617	2,326±565	2,108±838	0.36
%FEV1.0 (%)	95±18	96±17	95±18	0.98
Tumor location				–
RUL	19 (26.8)	20 (40.8)	6 (30.0)	
RML	5 (7.0)	3 (6.1)	2 (10.0)	
RLL	26 (36.6)	13 (26.5)	4 (20.0)	
LUL	11 (15.5)	6 (12.2)	1 (5.0)	
LLL	10 (14.1)	7 (14.3)	7 (35.0)	
Histology				0.19
Adenocarcinoma	53 (74.6)	36 (73.5)	11 (55.0)	
Squamous cell carcinoma	13 (18.3)	10 (20.4)	4 (20.0)	
Others	5 (7.0)	3 (6.1)	5 (25.0)	
c-Stage				0.98
0	1 (1.4)	0 (0.0)	0 (0.0)	
I	59 (83.1)	39 (79.6)	15 (75.0)	
II	8 (11.3)	7 (14.3)	3 (15.0)	
III	3 (4.2)	3 (6.1)	2 (10.0)	
IV	0 (0.0)	0 (0.0)	0 (0.0)	
Operative time (min)	144±40	161±43	158±33	0.066
Blood loss (g)	49±92	41±68	44±56	0.87
Significant vessel injury	1 (1.4)	3 (6.1)	2 (10.0)	0.12
Conversion to thoracotomy	3 (4.2)	3 (6.1)	1 (5.0)	0.87
Duration of postoperative drainage (days)	1.8±1.8	1.6±1.1	1.7±1.7	0.81
Postoperative hospitalization time (days)				
Mean	7±23	3.6±3.1	3.9±2.5	0.51
Median [IQR]	3 [2–4]	3 [2–3]	3 [2–4.5]	0.76
Morbidity (C-D classification grade ≥3)	10 (14.1)	7 (14.3)	4 (20.0)	0.76
Readmission within 30 days after the operation	3 (4.2)	5 (10.2)	2 (10.0)	0.51
30-day postoperative mortality	0 (0.0)	0 (0.0)	–	–
90-day postoperative mortality	0 (0.0)	0 (0.0)	–	–

Data are shown as mean ± standard deviation, n (%) or median [IQR]. ASA, American Society of Anesthesiologists; IQR, interquartile range; FEV, forced expiratory volume; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; C-D classification, Clavien-Dindo classification.

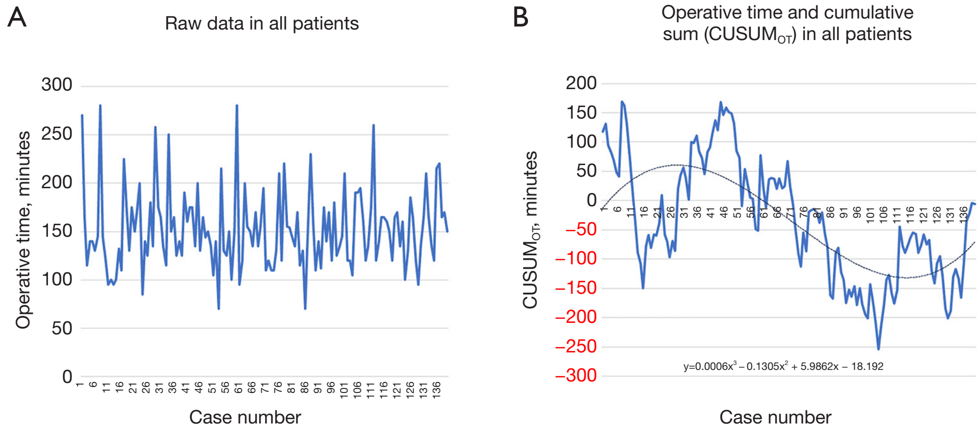

Figure 3 Raw data of operative time (A) and $CUSUM_{OT}$ learning curves (B) in all cases. The $CUSUM_{OT}$ learning curve was evaluated based on operative time and CUSUM. $CUSUM_{OT}$, operative time and cumulative sum.

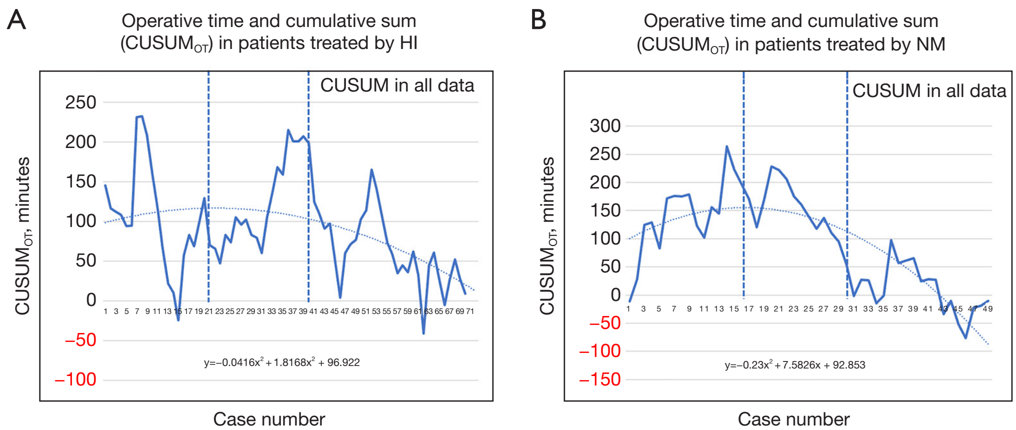

Figure 4 $CUSUM_{OT}$ learning curves of senior surgeons HI (A) and NM (B). The $CUSUM_{OT}$ learning curve was evaluated based on operative time and CUSUM.

by NM. Patient characteristics did not differ significantly between phases. Although the operative times were shorter in phases 2 and 3 than in phase 1, differences among the phases were not significant. The duration of postoperative drainage in phases 2 and 3 were significantly shorter than in the initial phase (P=0.026), but all other perioperative outcomes, including conversion rate, were equivalent between the phases. The conversion rates were 6.2% in phase 1, 7.1% in phase 2, and 5.3% in phase 3 (P=1).

Discussion

A consensus report from the Uniportal VATS Interest Group (UVIG) of the European Society of Thoracic Surgeons (ESTS) announced that the cutoff number required to overcome the learning curve is 50 cases, and that thoracic surgeons need to complete more than 40 cases annually to maintain their uniportal operative skills (15). It also advocated that surgeons should be supervised when initiating a uniportal thoracoscopic lobectomy program.

Although several previous reports have described the learning curve of uniportal thoracoscopic lobectomy, the number of cases required for learning varied. Vieira *et al.* reported that 60 cases were required for a surgeon to reach the transition phase, and that the surgeon became proficient after experiencing an additional 80 cases (6). Liu reported that the initial and transition periods each included 30 cases (9). Most groups have suggested that the learning curve for a surgical procedure can be divided into three phases, with the surgeon finally reaching proficiency

Table 3 Comparison of patient characteristics and perioperative results between phases for HI

Variables	Phase 1 (n=21)	Phase 2 (n=19)	Phase 3 (n=31)	P value
Age (years)	68±10	76±9.1	72±9.5	0.054
Sex				0.26
Female	9 (42.9)	6 (31.6)	17 (54.8)	
Male	12 (57.1)	13 (68.4)	14 (45.2)	
ASA score, median [IQR]	2 [1–2]	2 [1–2]	2 [1.5–2]	0.085
Smoking index (pack-years)	27±28	24±19	24±30	0.9
FEV1.0 (mL)	2,236±561	2,203±767	2,163±570	0.92
%FEV1.0 (%)	91±21	94±17	98±17	0.38
Tumor location				0.88
RUL	5 (23.8)	6 (31.6)	8 (25.8)	
RML	2 (9.5)	1 (5.3)	2 (6.5)	
RLL	7 (33.3)	8 (42.1)	11 (35.5)	
LUL	3 (14.3)	1 (5.3)	7 (22.6)	
LLL	4 (19.0)	3 (15.8)	3 (9.7)	
Histology				0.0068
Adenocarcinoma	19 (90.5)	10 (52.6)	24 (77.4)	
Squamous cell carcinoma	0 (0.0)	8 (42.1)	5 (16.1)	
Others	2 (9.5)	1 (5.3)	2 (6.5)	
c-Stage				0.41
0	0 (0.0)	0 (0.0)	1 (3.2)	
I	21 (100.0)	14 (73.7)	24 (77.4)	
II	0 (0.0)	3 (15.8)	5 (16.1)	
III	0 (0.0)	2 (10.5)	1 (3.2)	
IV	0 (0.0)	0 (0.0)	0 (0.0)	
Operative time (min)	150±52	148±28	138±36	0.47
Blood loss (g)	55±139	66±85	33±43	0.44
Significant vessel injury	1 (4.8)	0 (0.0)	0 (0.0)	0.56
Conversion to thoracotomy	3 (14.3)	0 (0.0)	0 (0.0)	0.04
Duration of postoperative drainage (days)	1.9±1.5	1.2±0.5	2.1±2.3	0.21
Postoperative hospitalization time (days)				
Mean	15±42	2.9±1.8	4.1±3.2	0.18
Median [IQR]	3 [2–3]	2 [2–3]	3 [2–4]	0.42
Morbidity (C-D classification grade ≥3)	3 (14.3)	0 (0.0)	7 (22.6)	0.088
Readmission within 30 days after the operation	0 (0.0)	0 (0.0)	3 (9.7)	0.078
30-day postoperative mortality	0 (0.0)	0 (0.0)	–	–
90-day postoperative mortality	0 (0.0)	0 (0.0)	–	–

Data are shown as mean ± standard deviation, n (%) or median [IQR]. ASA, American Society of Anesthesiologists; IQR, interquartile range; FEV, forced expiratory volume; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; C-D classification, Clavien-Dindo classification.

Table 4 Comparison of patient characteristics and perioperative results between phases for NM

Variables	Phase 1 (n=16)	Phase 2 (n=14)	Phase 3 (n=19)	P value
Age (years)	72±8	71±11	70±11	0.79
Sex				0.58
Female	6 (37.5)	7 (50.0)	6 (31.6)	
Male	10 (62.5)	7 (50.0)	13 (68.4)	
ASA score, median [IQR]	2 [1–2]	2 [2–2]	2 [1.5–2]	0.18
Smoking index (pack-years)	24±18	24±29	19±19	0.74
FEV1.0 (mL)	2,081±456	2,331±605	2,527±562	0.064
%FEV1.0 (%)	88±19	98±14	101±17	0.06
Tumor location				0.63
RUL	8 (50.0)	4 (28.6)	8 (42.1)	
RML	2 (12.5)	0 (0.0)	1 (5.3)	
RLL	2 (12.5)	5 (35.7)	6 (31.6)	
LUL	1 (6.2)	3 (21.4)	2 (10.5)	
LLL	3 (18.8)	2 (14.3)	2 (10.5)	
Histology				0.46
Adenocarcinoma	14 (87.5)	9 (64.3)	13 (68.4)	
Squamous cell carcinoma	2 (12.5)	3 (21.4)	5 (26.3)	
Others	0 (0.0)	2 (14.3)	1 (5.3)	
c-Stage				0.41
0	0 (0.0)	0 (0.0)	0 (0.0)	
I	14 (87.5)	12 (85.7)	13 (68.4)	
II	0 (0.0)	2 (14.3)	5 (26.3)	
III	2 (12.5)	0 (0.0)	1 (5.3)	
IV	0 (0.0)	0 (0.0)	0 (0.0)	
Operative time (min)	173±53	151±32	158±40	0.33
Blood loss (g)	48±59	48±96	30±49	0.68
Significant vessel injury	1 (6.2)	1 (7.1)	1 (5.3)	1
Conversion to thoracotomy	1 (6.2)	1 (7.1)	1 (5.3)	1
Duration of postoperative drainage (days)	2.2±1.6	1.2±0.8	1.3±0.7	0.026
Postoperative hospitalization time (days)				
Mean	4.7±4.9	3.1±1.8	3.2±1.3	0.25
Median [IQR]	3 [3–4.25]	3 [2–3]	3 [2–3.5]	0.3
Morbidity (C-D classification grade ≥3)	4 (25.0)	2 (14.3)	1 (5.3)	0.3
Readmission within 30 days after the operation	2 (12.5)	2 (14.3)	1 (5.3)	0.61
30-day postoperative mortality	0 (0.0)	0 (0.0)	–	–
90-day postoperative mortality	0 (0.0)	0 (0.0)	–	–

Data are shown as mean ± standard deviation, n (%) or median [IQR]. ASA, American Society of Anesthesiologists; IQR, interquartile range; FEV, forced expiratory volume; RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; C-D classification, Clavien-Dindo classification.

in the third phase (16-18). In contrast, Li *et al.* divided the learning curve into four phases based on 538 cases, which to our knowledge is the largest number of cases studied to date, with the surgeon entering phase 4 ("advanced proficiency") at approximately the 244th procedure (7). Therefore, the learning curve reported in this study may change in future with the accumulation of more experience.

Most previous studies have reported the learning curve for uniportal thoracoscopic lobectomy in a single surgeon. In contrast, we described the learning curves of two senior surgeons. HI initiated uniportal thoracoscopic lobectomy in our institution and required 21 cases to reach phase 2 and 40 cases to reach phase 3 (considered to be mastery). NM, who received supervision from HI, required 16 cases to reach phase 2 and 30 cases to reach phase 3, suggesting that supervision by HI positively affected the learning curve of NM. This result is very important for the introduction of this emerging less invasive approach. HI watched videos, read related articles, and attended courses and wet labs before the introduction of uniportal thoracoscopic lobectomy. Although this training is needed, direct supervision by a surgeon experienced in uniportal thoracoscopic lobectomy may help surgeons, including senior or junior, acquire proficiency more rapidly and effectively.

Operative time is an important factor for evaluating the quality of a surgical procedure, but other perioperative outcomes should also be assessed. Li *et al.* reported that most perioperative outcomes were improved across the phases, consistent with the reductions in operative time (7). Vieira *et al.* reported that operative time and several perioperative outcomes were improved across the phases, including intraoperative blood loss, postoperative drainage time, postoperative hospitalization, necessity of second incision, conversion to thoracotomy, and the number of harvested mediastinal lymph nodes (6). Both of these studies describing uniportal thoracoscopic lobectomy with mediastinal lymphadenectomy found that most variables were improved along the reductions in operative time. In contrast, some previous studies have reported significant differences in most variables across the phases, with only conversion rates improving along with improvements in operative times, which was similar to the perioperative results of HI reported here (8-10). We speculate that most surgeons tend to make the decision regarding conversion during the introduction period of uniportal thoracoscopic lobectomy to ensure the patient's safety. However, conversion rates were similar across the three phases in the perioperative results of NM, suggesting that direct supervision by an experienced surgeon can reduce conversion rates during the introduction period of uniportal thoracoscopic lobectomy.

In all cases, a convex upward function was observed until the 105th case, after which a convex downward function was observed, indicating that operative time was significantly longer after the case. This atypical change in the trend in $CUSUM_{OT}$ may be attributable to the emergence of new operative surgeons performing uniportal thoracoscopic lobectomy. In fact, the operative time in patients treated by HI was shorter than that in patients treated by NM or junior surgeons, although the difference was not significant. In contrast, no significant intergroup differences were observed between groups of surgeons. We conclude that supervision of all such operations in our department by HI ensured operative quality, although the operative times were longer. This finding reflects the importance of supervision by an experienced surgeon, as advocated by the UVIG of ESTS.

This study had some limitations in that the number of patients enrolled was relatively small; it also had a retrospective design and was conducted in a single institution. The number of cases each surgeon performed the operation for was different during the study period. Additionally, the emergence of new equipment and the presence of different surgical nurses or assistants may affect learning curves. Finally, the difficult part of the operative procedure in junior surgeons' group was occasionally performed by the experienced surgeon (HI), which might affect the insignificant difference between the groups.

Conclusions

The results of this study indicate that the inflection point of the learning curve for uniportal thoracoscopic lobectomy was achieved after 16–21 cases for surgeons highly experienced with previous multiportal thoracoscopy. This report is unique because it describes the learning curves of two senior surgeons in a single institution for uniportal thoracoscopic lobectomy with ND2a-1 or greater lymphadenectomy, unlike previous studies evaluating the effectiveness of supervision by an experienced surgeon. The results revealed that direct supervision by an experienced surgeon played an important role in avoiding the need for conversion to thoracotomy during the initial period, and facilitated the surgeon rapidly gaining proficiency with the surgical method.

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Footnote

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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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional ethics board of Japanese Red Cross Maebashi Hospital (approval No. 2022–05) and individual consent for this retrospective analysis was waived.

References

1. Rocco G, Martin-Ucar A, Passera E. Uniportal VATS wedge pulmonary resections. Ann Thorac Surg 2004;77:726-8.
2. Gonzalez D, Paradela M, Garcia J, et al. Single-port video-assisted thoracoscopic lobectomy. Interact Cardiovasc Thorac Surg 2011;12:514-5.
3. Al-Ameri M, Sachs E, Sartipy U, et al. Uniportal versus multiportal video-assisted thoracic surgery for lung cancer. J Thorac Dis 2019;11:5152-61.
4. Bourdages-Pageau E, Vieira A, Lacasse Y, et al. Outcomes of Uniportal vs Multiportal Video-Assisted Thoracoscopic Lobectomy. Semin Thorac Cardiovasc Surg 2020;32:145-51.
5. Hirai K, Takeuchi S, Usuda J. Single-incision thoracoscopic surgery and conventional video-assisted thoracoscopic surgery: a retrospective comparative study of perioperative clinical outcomes†. Eur J Cardiothorac Surg 2016;49 Suppl 1:i37-i41.
6. Vieira A, Bourdages-Pageau E, Kennedy K, et al. The learning curve on uniportal video-assisted thoracic surgery: An analysis of proficiency. J Thorac Cardiovasc Surg 2020;159:2487-2495.e2.
7. Li WH, Cheng H, Gan XF, et al. Learning curve of uniportal video-assisted thoracoscopic lobectomy: an analysis of the proficiency of 538 cases from a single centre. Interact Cardiovasc Thorac Surg 2022;34:799-807.
8. Bedetti B, Bertolaccini L, Solli P, et al. Learning curve and established phase for uniportal VATS lobectomies: the Papworth experience. J Thorac Dis 2017;9:138-42.
9. Liu X, Chen X, Shen Y, et al. Learning curve for uniportal video-assisted thoracoscopic surgery lobectomy-results from 120 consecutive patients. J Thorac Dis 2018;10:5100-7.
10. Nachira D, Meacci E, Porziella V, et al. Learning curve of uniportal video-assisted lobectomy: analysis of 15-month experience in a single center. J Thorac Dis 2018;10:S3662-9.
11. Zhou J, Shi Y, Qian F, et al. Cumulative summation analysis of learning curve for robot-assisted gastrectomy in gastric cancer. J Surg Oncol 2015;111:760-7.
12. Cela V, Freschi L, Simi G, et al. Robotic single-site hysterectomy: feasibility, learning curve and surgical outcome. Surg Endosc 2013;27:2638-43.
13. Okada M, Sakamoto T, Yuki T, et al. Selective mediastinal lymphadenectomy for clinico-surgical stage I non-small cell lung cancer. Ann Thorac Surg 2006;81:1028-32.
14. Clavien PA, Strasberg SM. Severity grading of surgical complications. Ann Surg 2009;250:197-8.
15. Bertolaccini L, Batirel H, Brunelli A, et al. Uniportal video-assisted thoracic surgery lobectomy: a consensus report from the Uniportal VATS Interest Group (UVIG)

of the European Society of Thoracic Surgeons (ESTS). Eur J Cardiothorac Surg 2019;56:224-9.
16. Chen L, Shen Y, Duan S, et al. Learning curve for uniportal video-assisted thoracoscopic anatomical segmentectomy. Ann Transl Med 2022;10:12.
17. Dimitrovska NT, Bao F, Yuan P, et al. Learning curve for two-port video-assisted thoracoscopic surgery lung segmentectomy. Interact Cardiovasc Thorac Surg 2022;34:402-7.
18. Arnold BN, Thomas DC, Bhatnagar V, et al. Defining the learning curve in robot-assisted thoracoscopic lobectomy. Surgery 2019;165:450-4.

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