

Novice training

The time course for developing competence in single port video-assisted thoracoscopic lobectomy

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Abstract

The competency in video-assisted thoracoscopic (VATS) lobectomy is expected to be achieved after surgeons practiced 30 to 50 cases according to previous reports. Does single port video-assisted thoracoscopic (SPVATS) lobectomy have a steeper learning curve and being harder to perform correctly, leading to long development times and high defect rates?

From January, 2014 to February, 2017, 8 individual surgeons (3 were novices, 5 were pioneers in SPVATS surgery) submitted their cases chronologically to evaluate the learning curve of SPVATS lobectomy. Operating time (OT) was set as a surrogate marker for surgical competency. Postoperative outcomes and OT between the 2 groups were compared using propensity score matching (1:1 nearest neighbor). The learning curve for OT was evaluated using the cumulative sum (CUSUM) method.

In the entire study cohort, a total of 356 cases were included (93 in junior consultant group [group A], 263 in senior consultant group [group B]). There were no significant differences between the 2 groups in operative time, conversion rate, postoperative complication rate, 30 and 90 days mortality rate. After propensity-score matching (86 pairs), operative time was longer in group A (214.33 ± 62.18 vs 183.62 ± 61.25 minutes, $P = .001$). Two-year overall survival rate was similar among 2 groups ($P = .409$). Competency was reached after junior surgeon completed 30th case of SPVATS lobectomy.

SPVATS lobectomy is safe for the novice surgeon who wants to adopt this new surgical approach under well-developed training program. The learning curves for competence in SPVATS lobectomy are similar to VATS lobectomy in our series.

Abbreviations: BMI = body mass index, CGMH = Chang Gung Memorial Hospital, CHUAC = Complejo Hospitalario Universitario de A Coruña, CUSUM = cumulative sum, ECOG = Eastern Cooperative Oncology Group performance status, FEV₁ = Forced expiratory volume in 1 second, SPH = Shanghai Pulmonary Hospital, SPVATS = single port video assisted thoracoscopic surgery.

Keywords: learning curve, novice, single port video-assisted thoracoscopic

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1. Introduction

Adoption of new surgery approach is a part of surgical advances. Initially, single port video assisted thoracoscopic surgery (SPVATS) was applied to minor procedures.^[1,2] With the advances in endoscopic surgical techniques and the ever-improving video thoracoscopic instruments, SPVATS recently raises a burst of upsurge in major lung resection,^[3] esophagectomy,^[4] and mediastinal tumor resection.^[5] Reports regarding to SPVATS have shown to be feasible and safe as traditional VATS or thoracotomy and have potential advantages of less perioperative pain, shorter hospital stay with similar lymph node yields and operation time.^[6–9] Despite of these reported advantages, the procedure is still performed at some specified centers, which could be due to steep learning curve. The new surgical approach might be technique demanding and have the risk of uncontrolled hemorrhage during lung anatomic resection. Nevertheless, how to strike a balance between patient safety, treatment effectiveness, and novice training is a paramount issue which is usually encountered when a new technology is being promoted. Previous published articles reveal that learning multiport VATS lobectomy needs to accumulate 30 to 50 surgical experience.^[10–12] Does learning SPVATS anatomic resection demand more cases? This article attempts to evaluate the surgical outcomes of a training

program of novice and compare perioperative parameters of lobectomy with senior SPVATS consultant

2. Methods

2.1. Patients

The study was approved by the local Institutional Review Board (IRB No: 2013/092, 201700805B0). A retrospective observation cohort study was performed by using prospectively established database from January, 2014 to February, 2017. A total of 442 consecutive patients who intended to receive SPVATS anatomic resection in the Minimally Invasive Thoracic Surgery Unit of Complejo Hospitalario Universitario de A Coruña (CHUAC, Spain) and Chang Gung Memorial Hospital (CGMH, Taiwan) were registered in this period, which including 16 pneumonectomy, 21 bilobectomy, 356 lobectomy, and 49 segmentectomy. Surgical indications were patients aged ≥ 18 years who underwent elective SPVATS lobectomy for primary lung malignancy, central located secondary lung malignancy, or benign lung tumor. Segmentectomy, bilobectomy, and pneumonectomy were excluded from this study. Finally, a total of 356 patients (93 in junior consultant group A, and 263 in senior consultant group B) were enrolled in the analysis. In order to mitigate the potential for selection bias across study groups, 86 matching pairs were selected for outcome comparisons based on propensity score method (Fig. 1A and B).

2.2. Senior and junior consultants

The junior consultants were 3 novices who began to perform SPVATS after January, 2014. Two were from CGMH and the other one was from CHUAC. From January, 2014, one self-

taught consultant who began to perform SPVATS in CGMH. Due to the lack of relevant SPVATS anatomic resection experience in CGMH, he participated SPVATS training course in Shanghai Pulmonary Hospital (SPH, Shanghai). The junior consultant had previously multiport VATS lobectomy experience, thereby gaining competency in the following steps of the SPVATS anatomic resection under Dr Diego's guidance in SPH training course. Another junior consultant from CGMH started to practice SPVATS minor procedures under the self-taught junior consultant's guidance. After he completed 50 cases of SPVATS minor procedures, he also participated SPH SPVATS training course and began to perform SPVATS anatomic resections since December, 2014. The other trainee was from CHUAC who achieved the prerequisite skills for performing SPVATS anatomic resection by performing >50 minor SPVATS procedures and obtaining experience by assisting in SPVATS anatomic resection, then began performing SPVATS anatomic resection with the help of well-trained assistants under the supervision of senior consultants. The senior consultants were defined as surgeons who performed SPVATS anatomic resections since 2010 in CHUAC.

2.3. Trainee education

In CHUAC, senior and junior consultants met together to discuss the case of the upcoming surgery and pointed out that the junior consultant might encounter difficulties during operation based on the image findings of computed tomography.

In addition, senior consultants would also provide junior consultant similar case surgical video. In CGMH, due to lack of associated surgical experience inheritance, junior consultants would search for similar cases of surgical videos from the Internet. If junior consultants still have doubt how to do the

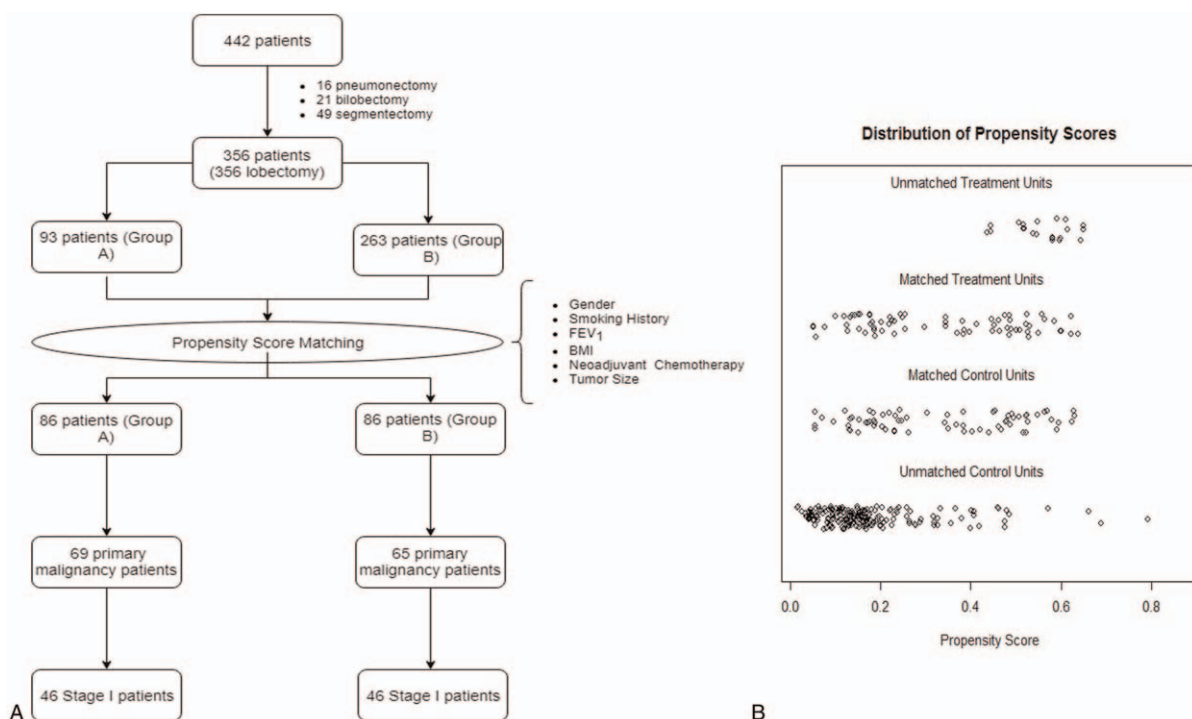


Figure 1. Detail information of entire enrolled cohort. (A) Flowchart of propensity score matching analysis. (B) Distribution of patients after propensity score match.

surgery for the difficult case, they would contact with Dr Diego and inquire his opinion. Each lobectomy done by junior consultants were recorded by digital recorder. If some unexpected accidents happened during operation, they would also inquire senior consultants' opinion post operation.

2.4. Surgical techniques

All surgeons performed SPVATS anatomic resections in a similar way: a 3 cm incision was created at the pivot of 4th or 5th intercostal space and anterior axillary line. A 10-mm, 30°, angled thoracoscopic video camera was placed at the top point of the incision wound allowing for other instruments in and out freely along the rest of incision wound. Plastic wound retractor was used based on surgeons' preference and whole procedure was completed without ribs spreading. Systemic lymphadenectomy was performed for malignant disease. Finally, a specimen bag was used for retrieval of the specimen.

2.5. Data collection

Preoperative characteristics (age, sex, Eastern Cooperative Oncology Group performance status [ECOG], pulmonary function, body mass index, smoking history, cardiac disease history, and previous malignant disease), intraoperative record (side, involved lobe, operative time, conversions, numbers of lymph node harvested, tumor size, final histological report), and postoperative data (in-hospital deaths, chest drainage duration, postoperative hospital stay, 30-day and 90-day mortality and mobility) were collected from electronic hospital information system. Postoperative complications were all gathered and classified them according to different groups.

2.6. Statistics

Intergroup differences in continuous variables were tested using independent Student *t* tests. Categorical data were compared using the Pearson chi-squared test or the Fisher exact test, as appropriate. Overall survival (OS) was calculated from the date of surgery to the date of death. Survival curves were plotted using the Kaplan–Meier method and compared using the log-rank test. Six items (sex, smoking, FEV₁ [forced expiratory volume in 1 second], BMI [body mass index], neoadjuvant, tumor size) were used to match 2 groups. The propensity scores matching were estimated using a multiple logistic regression. Two comparable treatment groups were identified using a 1:1 match ratio with caliper 0.2.^[13] The learning curve of SPVATS was measured as the operating time (OT) over the time course of the study. Cumulative sum (CUSUM_{OT}) method was used to analyze the learning curve. The CUSUM was the calculating total of differences between the individual values and the mean of all values. Graphical information of the trend in the OT of consecutive procedures was plotted by using the OT of patients chronologically arranged from the first to latest cases of surgery. The CUSUM_{OT} for the first case was the difference between the OT for the first case and the mean OT for all cases. The CUSUM_{OT} of the second case was the CUSUM_{OT} of the previous value added to the difference between the OT of the second case and the mean OT for all cases. The procedure was repeated for each patient except for the last case, which was calculated as zero. Linear regression was conducted to assess the sign of the slope of the regression for the learning curve.

Two-sided *P* values <.05 were considered statistically significant. Data analyses were performed with SPSS version 19 software (IBM, Chicago, IL) and R version 2.1.2 (R Foundation for Statistical Computing, Vienna, Austria)

3. Results

Based on the entire Cohort, 93 patients were in the junior consultant group (group A), and 263 patients were in the senior consultant group (group B). Their baseline clinical characteristics before propensity-score matching were shown in Table 1. There were significant differences in patients' sex (*P*<.001), smoking status (*P*<.001), BMI (*P*=.001), and FEV₁ (*P*=.04) (Table 1). Finally, we compared the perioperative postoperative outcomes between these 2 groups, and results showed that there were no significant differences in operation time, postoperative drainage duration, postoperative hospital stay, operation conversion rate, intraoperative bleeding episode, 30 and 90 days mortality rate (Table 2). Due to the uneven distribution of demographics and baseline characteristics, a propensity-score matching for balance group A and B was used to minimize the inherent selection biases. To this aim, we focused on pre-existing significant differences at the *P*≤.1 level in Table 1. Patients were matched in a 1:1 ratio using the nearest-neighbor method, without replacement. Finally, a total of 86 patient pairs were examined to estimate the potential differences between groups.

After propensity-score matching, there were no significant differences in each compared baseline clinical characteristics, as shown in Table 1. Except for operation time, no significant difference was observed in terms of intraoperative bleeding episodes and conversion rate, drainage duration, postoperative hospital stay (Table 2).

The postoperative pathological results of 2 consultant groups after propensity score matching were also listed in Table 1. There were totally 15 cases of benign lesions, 23 cases of secondary malignancy, and 134 cases of primary lung malignancy, which including 89 cases of adenocarcinoma, 26 cases of squamous cell carcinoma, 19 cases of carcinoid tumor, adenosquamous cell carcinoma, and large cell tumor. The median follow-up time among survivors was 17 months for all primary lung malignancy patients. Death occurred to 4 cases and 9 cases in the junior and senior consultant matched groups. The 2-year overall survival (OS) for the junior and senior matched groups were 84.4% and 84.9%. There was no significant difference in OS among 2 groups (Fig. 2A, *P*=.409). Because most of the matched constituent patients are stage I patients, we also compared the stage I OS between 2 matched groups, which still revealed no significant OS difference (Fig. 2B, *P*=.249) for all the matched cases.

We also analyzed the perioperative outcomes of 3 junior consultants individually. Figure 3A shows the mean operation time of SPVATS lobectomy performed by each junior consultant and senior consultant group. The mean operation time was similar to that of senior consultants group when the junior consultant A1 had completed 50 cases of SPVATS lobectomy. Under the premise that we set the mean operation time of senior consultant group as the target value of mature surgical skill of SPVATS lobectomy, operation times of junior consultant A1 were plotted in chronological procedure order. Learning curve of CUSUM method revealed that the study surgeon dramatically shortened the operation time after 30th case and maintained a relatively stationary slope after 43th case (Fig. 3B).

Table 1
Patient demographics and baseline characteristics before and after propensity matching (1:1).

Variable	Entire cohort			Propensity score matching		
	Group A (n=93)	Group B (n=263)	P-value	Group A (n=86)	Group B (n=86)	P-value
Age	63.86±11.37	64.94±11.65	.44	63.93±11.60	65.95±13.34	.07
Gender			<.01			.88
Male	53	200		52	51	
Female	40	63		34	35	
Smoking status			<.01			.92
No	58	63		51	49	
Former	16	104		16	18	
Current	19	96		19	19	
ACS history			.60			1.00
Yes	12	40		11	11	
No	81	223		75	75	
COPD			.59			.11
Yes	10	35		10	5	
No	83	228		76	81	
Additional primary malignancy			.21			.10
Yes	18	68		15	24	
No	75	195		71	62	
Body mass index	24.56±3.25	26.06±3.51	<.01	24.69±3.31	25.05±3.94	.63
ECOG			.70			.35
0	59	161		54	48	
1	34	102		32	38	
FEV ₁	2.20±0.58	2.36±0.66	.04	2.21±0.59	2.25±0.57	.54
FEV ₁ (%)	88.85%±16.18	81.36%±18.85	.01	89.20%±16.21	84.57%±20.24	.06
Neoadjuvant chemotherapy			.07			1.00
Yes	4	39		4	3	
No	89	224		82	83	
Diagnosis			.22			.53
Primary malignancy	76	231		69	65	
Secondary malignancy	9	21		9	14	
Benign	8	11		8	7	
Tumor location			.85			.77
RUL	35	95		35	31	
RML	9	17		4	8	
RLL	16	48		16	16	
LUL	18	59		17	15	
LLL	15	44		14	16	

ACS=Acute Coronary Syndrome, COPD=Chronic Obstructive Pulmonary Disease, ECOG=Eastern Cooperative Oncology Group performance status, FEV₁=forced expiratory volume in 1 second.

4. Discussion

The purpose of this study was to evaluate the single port VATS lobectomy learning curves. To our knowledge, we still didn't have much information about how many cases were needed to reach the acceptable of surgical results in single port VATS lobectomy. Bedetti et al^[14] found operation time, conversion, and complications rate tend to decline with cumulated surgical experience. Martin-Ucar et al^[15] reported postoperative outcomes during the learning curve period for single-port VATS lobectomies are not noticeably affected by previous multiport VATS experience.

In our report, we also have similar findings as previous report. The perioperative and postoperative results were not significantly different between junior and senior consultant groups after propensity score matching, except operation time. Actually, with the adaption to new surgical method, it would definitely bring new technique impacts to the surgeon. The major difference between traditional VATS and single port VATS was the change of the angle and the path during the process of cutting off the vessels, the bronchus, and the lung parenchyma. For beginners,

this will certainly increase the time for surgery to adapt to this change.

Given that single port VATS lobectomy is a technically demanding procedure, previous literature didn't provide an exact description for when the learning curve hit the established phase plateau.^[3,14,15] Our series provided a possible number for a novice to become competent to single port VATS lobectomy. Thirty cases might be needed for a junior consultant to adapt himself to such kind of new technique. The premise is that the novice might have sufficient VATS experience before he started to adopt this new technique. In the present study, we could construct a learning curve for single port VATS lobectomy into that was divided into 3 phases based on approximately 30 and 43 cases. The operating time during phase II (cases 30–43) decreased significantly compared with phase I (i.e., 188.77±41.92 vs 150.92±68.90 minutes; *P*=.032), which was primarily due to the improved competence of the surgeon. With the increase in surgical volume, junior consultant had a deeper understanding of the anatomy and surgical procedures of the 5 lobes of bilateral lung, and have more experience in operation procedure: especially manipulating instruments through a single incision

Table 2
Perioperative and postoperative outcomes before and after propensity score matching (1:1).

Variable	Entire cohort			Propensity score matching		
	Group A (n=93)	Group B (n=263)	P-value	Group A (n=86)	Group B (n=86)	P-value
Operation time	211.17 ± 62.34	201.94 ± 65.06	.24	214.33 ± 62.18	183.62 ± 61.25	<.01
Drainage Duration	4.11 ± 2.90	3.88 ± 2.95	.51	4.27 ± 2.95	3.61 ± 3.01	.07
Postoperative Hospital stay	5.37 ± 3.50	5.27 ± 3.92	.82	5.56 ± 3.56	5.17 ± 4.54	.47
N2 stations	2.69 ± 0.87	2.89 ± 2.04	.37	2.66 ± 0.90	2.91 ± 3.45	.50
Conversion to open surgery			.06			1.00
Yes	1	15		1	1	
No	92	248		85	85	
Conversion to multiple port VATS			.11			.50
Yes	2	1		2	0	
No	91	262		84	86	
Intraoperative Bleeding Episode			.38			.28
Yes	6	11		6	2	
No	87	252		80	84	
Postoperative complications			.12			.56
Prolonged Air leak (>5 days)	6	31		6	7	
Arrhythmia	2	12		2	2	
Atelectasis	2	4		2	1	
Subcutaneous emphysema	2	3		2	2	
Chylothorax	1	0		1	0	
Infection	1	9		1	4	
Stroke	0	1				
Postoperative bleeding	1	1		1	1	
Wound complications	0	2		0	1	
Yes	15	63		15	18	
No	78	200		71	68	
30-day mortality rate	0	0.70%	.40	0	1.10%	.50
90-day mortality rate	0	0.70%	.40	0	1.10%	.50

VATS=single port video assisted thoroscopic surgery.

wound smoothly without interference, passing the vessels with staple with confidence, which have significantly improved the efficiency of lobectomy procedure and shorten the operation time. During 43th to 50th cases (phase III), the junior surgeon

encountered some difficult cases, such as neoadjuvant chemotherapy patients and unexpected intraoperative bleeding episodes, which result in longer operation time, but still maintained a relatively stationary operation time.

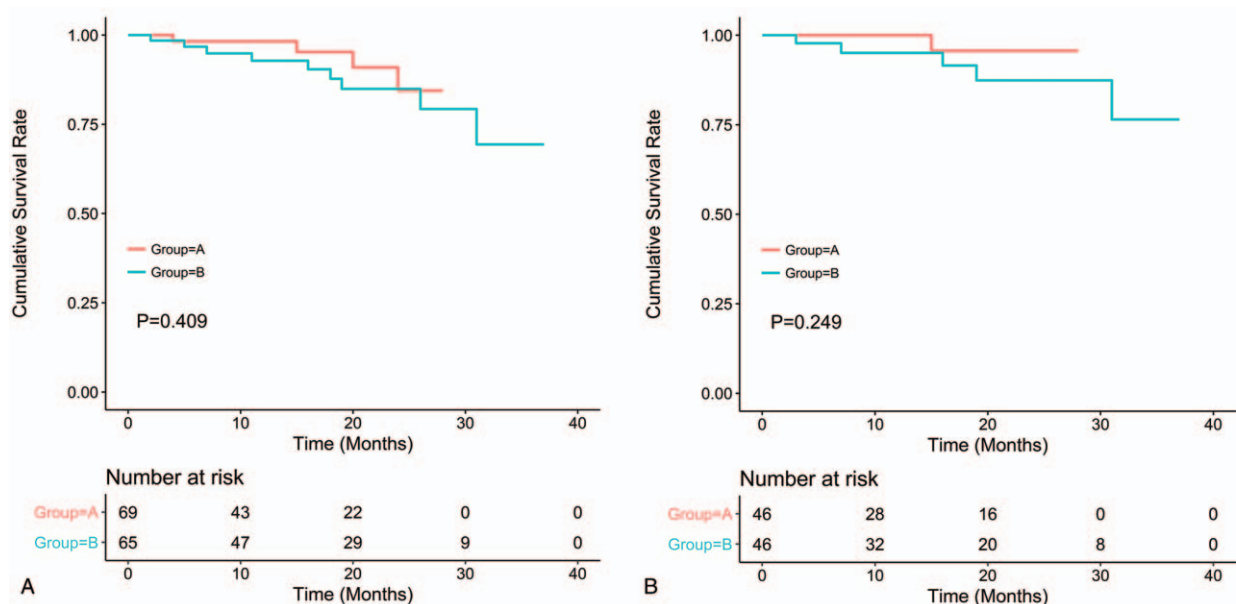


Figure 2. The overall survival (OS) between junior consultant group (group A) and senior consultant group (groupB). (A) Two-year OS of whole matched group, P=.409. (B) Two-year OS of stage I primary lung cancer patients, P=.249.

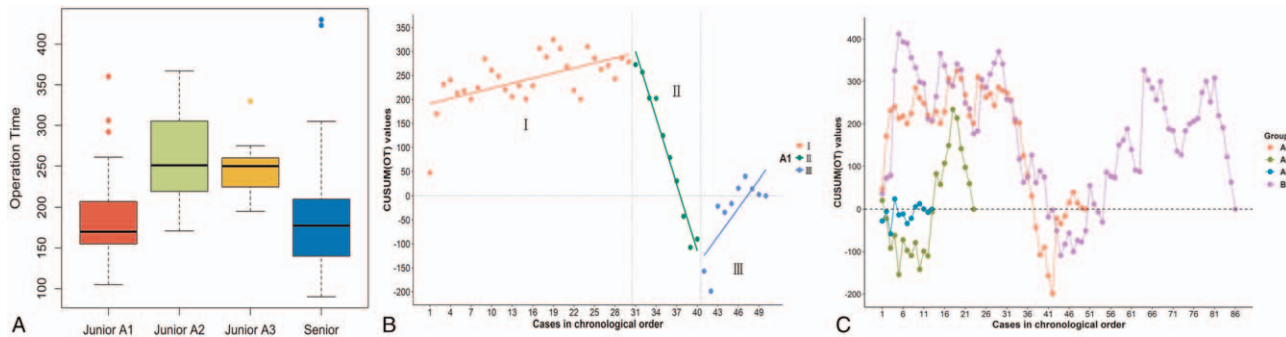


Figure 3. Learning curve analysis of operating time for 3 junior consultants. (A) Mean operative time comparison among 3 junior consultants (Junior A1, Junior A2, and Junior A3) and senior consultants group after propensity matching. (B) Change point analysis of junior consultant A. (C)

In the present study, there were no significantly differences in conversion rate, intraoperative bleeding episodes, postoperative complications, and 2-year survival rate between 2 matches groups. Before letting novices lead lobectomy, we would arrange a systematic training course, such as laboratory animal workshop, surgical symposium, operation assistant, and minor SPVATS surgery for novices to become familiar with surgical technique. The novices could also perform the major surgery with ease when standing on the main operator position under the guidance of an experienced supervisor. This might be one of the reasons for similar perioperative and postoperative results between 2 groups in our experience. In recent years, the complication rate of VATS lobectomy was reported to be 15.3% to 23.2%.^[11,16–18] It was 21.9% in our series, which was similar to the complication rate reported by other’s experience.^[19]

Previously some of scholars consider that the increased difficulty of performing VATS may result from lack of experience inheritance from experienced surgeon, prolong operation time and difficulty of management of intraoperative complications.^[20–22] However, as internet speeds up the free flow of information, subscribing master’s youtube video, participating a high-intensity training course could also help novices quickly

cross the learning barrier. As with the VATS lobectomy, SPVATS lobectomy appears to require a minimum of 30 cases to be competent to such kind of new procedure. Our series proved that SPVATS doesn’t have a steeper learning curve and being harder to perform correctly, leading to long development times and high defect rates.

Initially, SPVATS was thought to be more feasible for lower lobe lobectomy,^[2,3] however, with the advancement of surgical skill, SPVATS surgery was proven feasible for any kind of anatomic resection.^[3,8] Eventually, lower lobe lobectomy was seen as a good starting point for novices. However, in our chronological analysis of the entire and matching cohort (Fig. 4A and B), we found a longer mean operation time for non-lower lobectomy, compared with lower lobectomy, but it did not achieve statistically significant differences. This may be due to the fact that although single port VATS is more suitable for lower lobe resection, we had to gradually overcome innate structural constraints in our training system. Of course, this was also limited by the small number of our cohort. Further evaluation is warranted.

There are some of potential drawbacks to this study. Relatively small numbers of enrolled patients and junior surgeons might

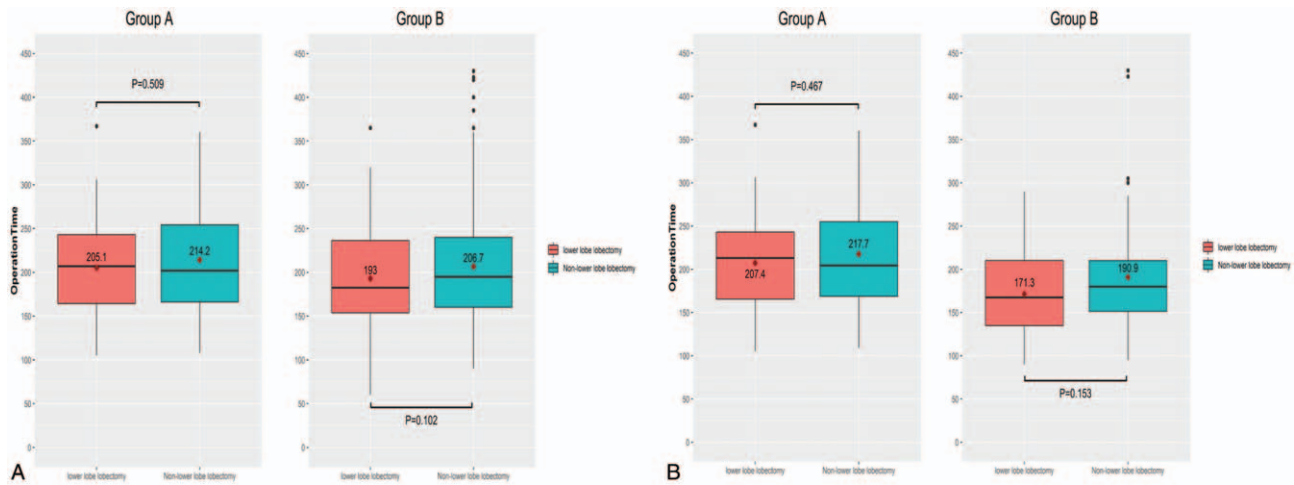


Figure 4. Lower lobe lobectomy and non-lower lobe lobectomy operation time (A) entire cohort: 205.1 ± 59.4 minutes versus 214.2 ± 64.0 minutes ($P=0.51$) for the junior consultant group and 193.0 ± 58.9 minutes versus 206.7 ± 67.8 minutes ($P=.10$) for the senior consultant group. (B) Matching cohort: 207.4 ± 59.1 minutes versus 217.7 ± 64.2 minutes ($P=.47$) for the junior consultant group and 171.3 ± 48.9 minutes versus 190.9 ± 66.9 minutes ($P=.15$) for the senior consultant group.

limit the application of our results to the general learning condition of novices. However, our study proved that the learning time course of developing competence in SPVATS lobectomy is similar to traditional VATS lobectomy in our SPVATS training environment. Certainly, data from different continents and cultures might produce different characteristics between the patient groups. For example, Riquet et al^[24] found that after lung cancer resection and complete lymphadenectomy, the number of LNs is subject to normally distributed interindividual variability, which was also found in our previously published paper.^[18] Even though we all performed complete lymph node dissection, the average lymph node numbers differed in 2 enrolled centers. This is why we do not use the number of harvesting lymph nodes as an objective criterion for the learning curve.

Thus, we used the propensity score matching to reduce the potential bias between 2 groups. However, a retrospective study might cause some inevitable bias. New surgical technique learning is a dynamic process. Although we focus on SPVATS lobectomy learning, performing other types of SPVATS anatomic resection, such as bilobectomy, segmentectomy, and pneumoectomy, will also increase the competence of new skill. Nevertheless, different surgical procedures also bring different postoperative complications and difficulty in surgery. These effects on the learning curve are very difficult to be translated into clinical research terms. In addition, limited by the cases numbers, how many cases are needed to achieve proficiency in performing SPVATS lobectomy still needed enrolled more patients to validate it.^[12] Further evaluation is warranted.

To sum up, the times course of learning SPVATS lobectomy is similar to that of learning VATS. Even the surgeons are the novices in this field, they could achieve comparable perioperative and postoperative clinical results under well-developed training course.

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