Ann Thorac Cardiovasc Surg 2022; 28: 121–128
Online September 23, 2021
doi: 10.5761/atcs.oa.21-00111

Original Article

Efficacy of the Segment-Counting Method in Predicting Lung Function and Volume Following Stapler-Based Thoracoscopic Segmentectomy

Nobuyuki Yoshiyasu, MD,[1,2] Fumitsugu Kojima, MD, PhD,[1] Hirotomo Takahara, MD,[1] and Toru Bando, MD, PhD[1]

Purpose: To investigate the accuracy of a segment-counting method in predicting lung function and volume after stapler-based thoracoscopic segmentectomy in comparison with lobectomy.
Methods: Between 2014 and 2018, patients who underwent these procedures were retrospectively reviewed. Thoracic computed tomography and spirometry data before and 1 year after the surgery were assessed. We evaluated the differences between the predicted values using a segment-counting method and the actual postoperative values for lung function and volume in each group. Sub-analyses were also performed to assess the impact of the number of staples and resected segments in predicting patient outcomes.
Results: We included 116 patients (segmentectomy, 69; lobectomy, 47). Actual postoperative lung function and volume values matched the predicted values in the stapler-based segmentectomy group, and significantly exceeded the predictions in the lobectomy group (P <0.01). Sub-analyses revealed lower postoperative lung function values than predicted existed after single segmentectomy, with an odds ratio of 3.29 (95% confidence interval: 1.02–10.70, P = 0.04) in a multivariable analysis. The degree of predicted error regarding lung function was negligible.
Conclusions: The segment-counting method was useful in predicting lung function after stapler-based thoracoscopic segmentectomy. Segmentectomy rarely yielded lower-than-predicted lung function and volume values.

Keywords: lung cancer, stapler-based thoracoscopic segmentectomy, stapling procedure

[1]*Department of Thoracic Surgery, St. Luke's International Hospital, Tokyo, Japan*
[2]*Department of Thoracic Surgery, The University of Tokyo Hospital, Tokyo, Japan*

Received: May 23, 2021; Accepted: August 14, 2021

Corresponding author: Fumitsugu Kojima, MD, PhD. Department of Thoracic Surgery, St. Luke's International Hospital, 9-1 Akashicho, Chuo-ku, Tokyo 104-8560, Japan
Email: fmkojima@luke.ac.jp

Introduction

With the recent increase in the number of patients presenting with early-stage lung cancer, the use of segmentectomy, which contributes to the preservation of lung function (LF), has increased.[1,2] Advances in medical equipment[3] have allowed this complicated surgery to be performed with relative safely. The use of automatic suture instruments, for example, have become common in procedures involving the resection of lungs and vessels.[4] Some sources report that resection by staplers may lead to less blood loss, shorter operating times, and less pulmonary air leakage than by electrocautery.[5] In contrast, it has also been determined that when lung parenchyma is separated with staples, postoperative atelectasis and peri-staple hematomas may occur.[6,7] Further, the tucking up of parenchymal tissue with sturdy staples may lead to insufficient postoperative lung expansion,[8,9] which may interfere with the postoperative recovery of pulmonary function and volume. However, there is limited evidence regarding the postoperative LF and volume following thoracoscopic surgery by using staplers, as opposed to open surgery. In the present study, we investigated the efficacy of the conventional segment-counting method in predicting LF and lung volume after stapler-based thoracoscopic segmentectomy in comparison with lobectomy.

Materials and Methods

The patients' medical records were retrospectively reviewed under a waiver of authorization and consent, and was approved by St. Luke's International Hospital (No. 19-R094, May 22, 2019). This study was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Patients

Between January 2014 and March 2018, 348 patients underwent lung resection by thoracoscopic surgery (lobectomy, 176; stapler-based segmentectomy, 172) at our institution. Thin-section computed tomography (CT) and spirometry findings obtained before and 1 year after the operations were assessed for all patients after applying the following exclusion criteria: (1) no postoperative CT and/or spirometry performed in the observation period ($n = 168$), (2) the number of staples in the residual lungs was unclear due to segmentectomy following partial resection for intraoperative diagnosis such as staple on staple ($n = 11$), (3) additional procedures for air leakage, such as direct suturing or usage of polyglycolic acid sheets and fibrin glue, pleurodesis ($n = 26$), and (4) past medical history of pulmonary resection ($n = 27$). Finally, 116 patients (thoracoscopic lobectomy, 47; stapler-based thoracoscopic segmentectomy, 69) were included in this study.

Evaluation of lung functions and volumes

For the patients enrolled in this study, spirometry was conducted before and 1 year after the operations. Thin-section CT images were also taken to assess the pulmonary condition at the same time points. LF assessments were performed by measuring the forced vital capacity (FVC) and forced expiratory volume in 1 sec (FEV1). Total lung volume (TLV) was evaluated using three-dimensional CT images with SYNAPSE VINCENT software (Fujifilm Medical, Tokyo, Japan). The predicted postoperative (ppo) values for each variable were calculated using the following formula[10,11]:

$$\text{ppoX} = \text{preoperative X} \times (19 - \text{the number of resected segments})/19,$$

where X corresponds to the FVC, FEV1, or TLV. The differences between the actual postoperative and ppo values, which was the predicted error, for LF and volume measurements were compared in the thoracoscopic lobectomy and segmentectomy groups. We also evaluated the predicted error of the LF and TLV values for each number of resected segments in both groups. Furthermore, the following value was assessed:

$$\text{The predicted rate of X (\%)} = \text{postoperative X/ppoX}.$$

For subgroup analyses in the segmentectomy group, we investigated the risk factors that would determine a lower-than-ppo LF. Prediction of these values with the segment-counting method was inaccurate. The risk factors included the following clinically relevant perioperative variables: age (>65 years), sex (male), positive smoking history, lung disease (interstitial pneumonia and/or chronic obstructive pulmonary disease), the number of staples dividing the lung parenchyma (≥5), single segmentectomy, operative time (>3 hr), and the number of days to the removal of the chest drain (≥2). The thickness and type of staples were not considered.

Surgical procedure

Thoracoscopic lobectomy and segmentectomy were performed under general anesthesia with double-lumen intubation. For both operative procedures, three surgical incisions were made.[12] The largest wound had a diameter of 3 cm and was made to pull out the resected specimen. Segmentectomy was indicated for: (1) nodules less than 2 cm in size, (2) pure ground glass or part-solid nodules on CT, and (3) suspected metastases from other cancers. For nodules that were relatively far from the visceral pleura, to prevent insufficient margins, virtual-assisted lung mapping (VAL-MAP) before segmentectomy[13] was performed. In addition, when resecting the pulmonary artery and vein and the bronchus,

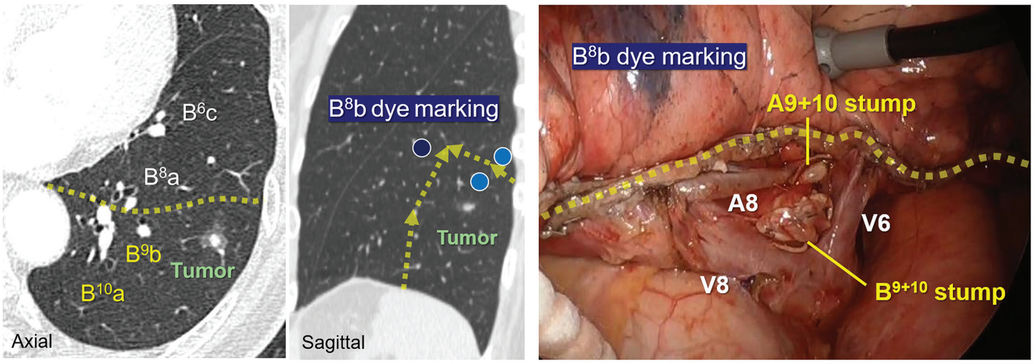

Fig. 1 A case of thoracoscopic stapler-based segmentectomy for the left basilar segments (S9 + 10). The axial and sagittal computed tomography (CT) images indicate the location of a part-solid nodule. Yellow dotted lines in the CT images are planned routes to fire staples and the actual staple lines in this operation. Three blue circles indicate the area of dye markings, which include the B^{8}b marking (darker blue).

intersegmental planes were created by staples alone and electrocautery was not used. During the thoracoscopic lobectomy, staples were fired only into the interlobar planes and were not used to divide the lung parenchyma. In contrast, for stapler-based thoracoscopic segmentectomy, staples were used for dividing both interlobar planes and lung parenchyma. In our team, when determining the resecting lines, we did not adhere to the exact intersegmental planes but rather prioritized an adequate surgical margin from the tumors.

The findings for a case of stapler-based thoracoscopic segmentectomy for left basilar segments (S9 + 10) performed at our hospital are presented in **Fig. 1**. A part-solid nodule, 15 mm in size, can be seen at the lateral basal segment in the left lung. To maintain the surgical margin, three dye markings by bronchoscopy were made preoperatively in accordance with the VAL-MAP technique. Among these three markings, one was planned near the tumor through B^{9}a. The other two markings were made on the surface of the residual lung via B^{6}c and B^{8}b, which were on the borders between the superior segment (S6) or anterior basal segment (S8) and the basilar segments (S9 + 10). A total of seven staples were used on the lung parenchyma for resection.

Statistical analysis

Continuous variables are presented as medians with interquartile ranges and compared using the Mann–Whitney U test. Categorical variables are reported as frequencies and percentages, and compared using the χ^2 test. In the stapler-based segmentectomy group, univariable and multivariable logistic regressions were used to estimate the relevant risk factors for lower-than-ppo LF values. A P <0.05 was considered statistically significant. All analyses were conducted with the statistical software R (Ver. 3.4.3) (R Foundation for Statistical Computing, Vienna, Austria).

Results

This retrospective study was conducted with 116 patients who underwent pulmonary resections by thoracoscopic approach. Of these, 69 (58%) constituted the stapler-based segmentectomy group. **Table 1** shows the demographic characteristics of participants in the lobectomy and segmentectomy groups. The two groups showed no significant differences in baseline preoperative LF and volume values. None of the patients showed severe pulmonary dysfunction (FEV1 <1.5 L). The median number of staples used for dividing lung tissues was five in the segmentectomy group and two staples in the lobectomy group. **Table 2** demonstrates the resected regions in each group. In the segmentectomy group, right resection was performed in 38 patients (single segmentectomy: 31; multiple segmentectomy: 7) and left resection in 31 patients (single segmentectomy, 9; multiple segmentectomy, 22). VAL-MAP was performed for 32 patients (46%) in the stapler-based segmentectomy group.

For the prediction accuracy of segment-counting method, the mean predicted rates of FEV1 were 99 ± 7% in segmentectomy group and 111 ± 10% in lobectomy group (P <0.001). Also, the mean predicted rates of FVC were 99 ± 7% in segmentectomy group and 111 ± 15% in lobectomy group (P <0.001). However, the mean predicted values of TLVs were 107 ± 13% for the segmentectomy group and 116 ± 13% (P <0.001). In the evaluations of predicted error, the difference between the

Table 1 Overall characteristics of patients who underwent thoracoscopic lobectomy and stapler-based thoracoscopic segmentectomy

Variables	Lobectomy (*n* = 47)	Stapler-based segmentectomy (*n* = 69)	*P*-value[a]
Age (years)[b]	67 (62–72.5)	66 (58–72)	0.523
Male, *N* (%)	36 (76.6)	32 (46.3)	0.002
BMI (kg/m[2])[b]	22.7 (21.1–25.3)	23.2 (21.5–24.7)	0.998
History of smoking, *N* (%)	33 (70.2)	38 (55.1)	0.108
Number of used staples in parenchyma[b]	2 (1–3)	5 (4–6)	<0.01
COPD, *N* (%)	6 (12.8)	6 (8.7)	0.663
IP, *N* (%)	9 (19.1)	7 (10.1)	0.248
FEV1 (L)[b]	2.41 (2.03–2.81)	2.33 (1.99–2.76)	0.906
ppoFEV1 (L)[b]	1.89 (1.62–2.17)	2.15 (1.82–2.51)	<0.01
FVC (L)[b]	3.41 (2.94–3.84)	3.33 (2.73–3.81)	0.444
ppoFVC (L)[b]	2.70 (2.29–3.11)	3.05 (2.54–3.47)	<0.01
DLCO (ml/min/mmHg)[b]	18.1 (14.9–22.3)	18.7 (15.7–22.2)	0.731
Total lung volumes (L)[b]	4.53 (4.05–5.13)	4.31 (3.82–5.22)	0.365
Operative time (min)[b]	197 (170–218)	177 (146–207)	<0.01
Drainage periods (days)[b]	2 (1–4)	1 (1–2)	<0.01

[a]*P*-value in the Mann–Whitney U test. [b]Continuous characteristics are expressed as the median (interquartile range). BMI: body mass index; COPD: chronic obstructive pulmonary disease; DLCO: diffusing capacity of the lungs for carbon monoxide; FEV1: forced expiratory volume in 1 s; FVC: forced vital capacity; IP: interstitial pneumonia; ppo: predicted postoperative value

Table 2 Resected regions in each procedure by thoracoscopic lobectomy and stapler-based segmentectomy (single and multiple segmentectomy)

Lobectomy	(*n* = 47)	Single segmentectomy	(*n* = 40)	Multiple segmentectomy	(*n* = 29)
Right upper lobe	19	S1	4	S1 + 2	1
		S2	5		
		S3	8		
Right lower lobe	11	S6	11	S6 + 8	1
		S7	1	S8 + 9	2
		S10	2	S9 + 10	3
Left upper lobe	12	S3	3	S1 + 2	10
				S1 + 2 + 3	8
				S4 + 5	2
Left lower lobe	5	S6	4	S9 + 10	2
		S8	1		
		S10	1		

S: segment

postoperative and predicted values was verified for FVC, FEV1, and TLV values (**Fig. 2A**). The median difference in FVC was 270 mL (16–442 mL) for thoracoscopic lobectomy and −31 mL (−169 to −110 mL) for the segmentectomy. The median difference in FEV1 was 189 mL (69–305 mL) for the lobectomy and −57 mL (−164 to −93 mL) for the segmentectomy. The median difference in TLV was 585 mL (333–861 mL) for the lobectomy and 236 mL (13–471 mL) for the stapler-based thoracoscopic segmentectomy. In the segmentectomy group, all postoperative LF and volume values were almost equal to the predicted values. The predicted error of LFs and volume after segmentectomy was significantly smaller and lower than those of lobectomy ($P < 0.01$).

In terms of the number of patients who had both higher FVC and FEV1 than their predictions, the lobectomy group had 35 patients (74%), while the segmentectomy group had 30 patients (43%). In the lobectomy group, staples for dividing interlobar planes were used for 38 patients (81%). However, no significant difference in the preoperative predicted- and postoperative LFs was observed between patients with and without staple (**Supplementary Table**, available Online).

The results of the patients who underwent single and multiple stapler-based segmentectomy are shown in **Fig. 2B**. The mean predicted rates of FEV1 were 97 ± 7% for single group and 101 ± 8% for multiple group (P = 0.009) as well as those for FVC (P = 0.043).

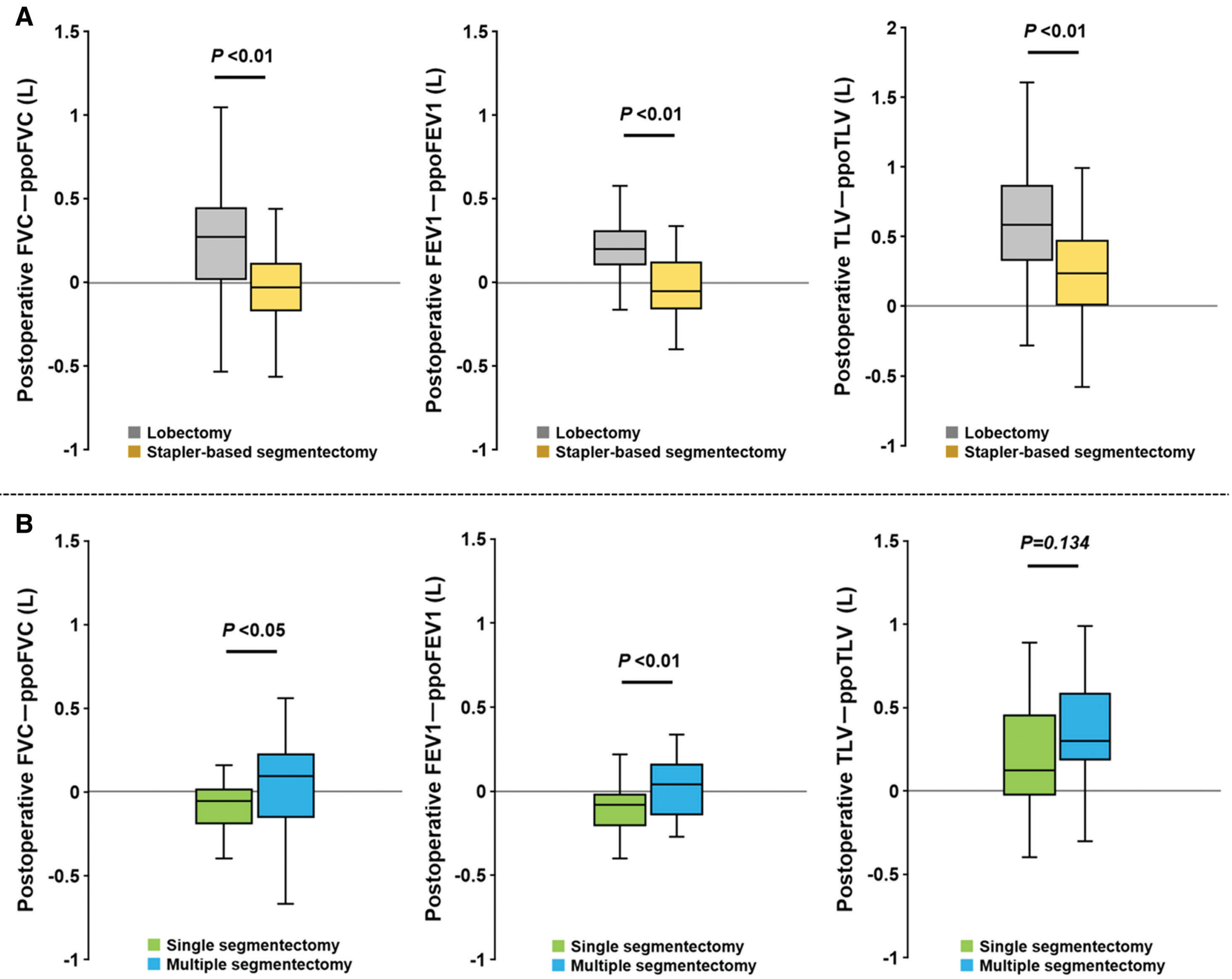

Fig. 2 (**A**) Upper row: the difference between actual and predicted (ppo) values for FVC, FEV1, and TLV in the thoracoscopic lobectomy and stapler-based segmentectomy groups. (**B**) Lower row: the difference between actual and predicted (ppo) values for FVC, FEV1, and TLV in the stapler-based segmentectomy (single and multiple segmentectomy). FEV1: forced expiratory volume in 1 s; FVC: forced vital capacity; TLV: total lung volume based on three-dimensional volumetry

Moreover, the mean predicted rates of TLV were 107 ± 15% in the single group and 108 ± 10% in the multiple group ($P = 0.646$). All predicted error values for LF showed significant differences between the two groups. The predicted error for FVC and FEV1 for multiple segmentectomy was 95 mL and 40 mL, respectively, which were higher than the values for the single segmentectomy (−56 ml for FVC, $P = 0.016$; −83 ml for FEV1, $P = 0.006$, respectively). However, the predicted error values for TLV approached significance. The predicted error of TLV was 300 mL in the multiple segmentectomy, which was higher than that of the single segmentectomy (122 mL) with no significant difference ($P = 0.134$).

In the stapler-based thoracoscopic segmentectomy group, there were 39 patients (56%) with lower-than-ppo LF values. Subgroup analyses were also performed to investigate the clinical risk factors for the lower-than-ppo LF values. In the univariable and multivariable analyses, single segmentectomy was a risk factor (**Table 3**). For a single segmentectomy, the odds ratio was 4.25 (95% confidence interval [CI]: 1.52–11.90, P <0.01) on univariate analysis and 3.29 (95% CI: 1.02–10.70, $P = 0.04$) on multivariable analysis. No associations between the number of fired staples for dividing lung tissue and lower-than-ppo LF were noted.

Discussion

Automatic suture instruments have been used for stapler-based segmentectomy in the cases of lung cancer at many centers.[14–16] However, there is limited evidence

Table 3 Clinical risk factors leading to lower postoperative lung function than the predicted values among patients undergoing stapler-based thoracoscopic segmentectomy in univariable and multivariable analyses

Variables	Univariable		Multivariable	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Age >65 years	0.46 (0.17–1.29)	0.14	0.58 (0.17–2.04)	0.39
Male	0.54 (0.21–1.45)	0.22	0.76 (0.23–2.45)	0.64
Ever-smoker	0.97 (0.37–2.56)	0.95	0.92 (0.28–3.05)	0.89
IP and/or COPD	4.33 (0.49–38.20)	0.19	7.11 (0.66–76.60)	0.11
Number of staples used in parenchyma ≥5	1.00 (0.36–2.79)	1.00	1.01 (0.28–3.61)	0.99
Single segmentectomy	4.25 (1.52–11.90)	**<0.01**	3.29 (1.02–10.70)	**0.04**
Operative time >3 hr	0.66 (0.25–1.76)	0.41	0.96 (0.27–3.41)	0.95
Drainage periods ≥2 days	0.63 (0.23–1.69)	0.35	0.68 (0.21–2.18)	0.52

Bold phase indicates *P*-value less than 0.05. CI: confidence interval; COPD: chronic obstructive pulmonary disease; IP: interstitial pneumonia; OR: odds ratio

regarding the efficacy of the conventional segment-counting method in predicting LF and volume following stapler-based thoracoscopic segmentectomy. Moreover, the impact on the residual lungs following the thoracoscopic segmentectomy is unclear. To the best of our knowledge, few studies to date have evaluated the influence of the number of resected segments and staples used to divide lung tissues, or the stapling procedure itself on postoperative LF and volume. Thus, we investigated all these aspects in the present study. To minimize the effect factors other than the stapling procedure on the residual lungs, we excluded the patients with a history of additional procedure for air leakage or pleural effusion.

Our cohort was suitable for assessing the stapling procedure's efficacy in preserving the residual lung because all resection lines were created by staples. There are two main methods to divide intersegmental planes or lung tissues in stapler-based thoracoscopic segmentectomy. The classical approach is to divide them by electrocauterization along the direction of intersegmental veins.[17,18] The other approach, a stapling procedure, involves dividing lung parenchyma by assuming intersegmental planes using automatic suture instruments.[8,19] Some previous studies have compared lobectomy and segmentectomy on the basis of LF values and 3D lung volumetry findings. These studies evaluated LF before and after operations by scintigraphy or residual volumes based on 3D volumetry.[20,21] However, the methods used to make intersegmental planes, such as staple or electrocautery, were not considered in these studies.

Our results, which are based on only the stapling procedure, suggest that the LF and volume after thoracoscopic lobectomy were much higher than predicted. After thoracoscopic segmentectomy, lung volumes were slightly higher than predicted, but postoperative LF values were equivalent to the predicted values. However, in the segmentectomy, 39 cases (56%) had lower-than-ppo LF values. To investigate the cause, subgroup analysis was performed. According to the result, performing a single segmentectomy was significantly associated with lowered LFs. In terms of the predicted error in TLV following single and multiple segmentectomy, there was no significant difference but a tendency for higher-than-predicted volumes in those who underwent multiple segmentectomy.

There were some possible factors influencing the different results between the thoracoscopic lobectomy and segmentectomy. First, the difference in the room for lung expansion was considered. After the lobectomy, there was more space for the residual lungs to expand compared to the segmentectomy because larger lung volumes had been resected. Therefore, the difference was considered to have occurred due to the postoperative LF being beyond the prediction in the lobectomy and equivalent to the prediction in the segmentectomy. A similar phenomenon was considered as the cause for the different outcomes observed between the single and multiple segmentectomy groups.

Second, the different stitching strength caused by varying quantity and placement of staples might have affected the result. There was a significant difference in the number of staples in the parenchyma, namely two for the thoracoscopic lobectomy group and five for the segmentectomy group. Staples were used only for separating thin interlobar fissures in the lobectomy, whereas they were fired for dividing thick parenchyma in the segmentectomy. However, although sub-analysis between single and multiple segmentectomy showed significant differences in the predicted error of LFs, the stitching strength might have been irrelevant, exerting a minimal impact as the number of staples was the same in each group.

Third, according to the sub-analysis, there could be another cause as to why single segmentectomy became a risk factor for lower-than-ppo LF values. A research group reported contrary results following thoracotomy showing that a lower-than-ppoFEV1 was seen in a segmentectomy of ≥2 segments than in that of a single segmentectomy.[22] This study utilized electrocautery to cut the intersegmental plane along the intersegmental vein in shallow lung tissue. In contrast, our single segmentectomy using staples under thoracoscopic surgery had a higher likelihood of achieving an extended resection to maintain an adequate surgical margin, which may have resulted in a lower-than-ppo LF values. Dividing the intersegmental planes exactly can result in insufficient surgical margins. Because the priority policy of our surgical procedure was to maintain sufficient tumor margins and preserve postoperative LF, VAL-MAP was often conducted before surgery.[13] According to our treatment policy, we sometimes created resection lines beyond the anatomical intersegmental planes and resected part of the adjacent segments en bloc, especially when performing single segmentectomy. Due to this, we may have resected a portion slightly larger than the anatomical segment which might have resulted in lower LF than the predicted values.

Limitations

There are a few limitations to this study. First, the study design was based on a retrospective cohort and conducted at a single medical center. The number of patients was relatively small. Second, we did not assess the differences between stapler-based segmentectomy and segmentectomy by electrocautery. Finally, this study focused on the condition of LF and TLV 1 year after the operations. Thus, the short-term effects were not evaluated and discussed.

Conclusions

Although there are concerns that stapler-based thoracoscopic segmentectomy will lead to more volume loss and lower LFs than expected, they were mostly equivalent to the predicted values in this study. In contrast, the LFs and volume after thoracoscopic lobectomy were much higher than predicted, compared to after segmentectomy. In the segmentectomy group, we experienced several cases that had lower-than-ppo LF, although the degree was statistically insignificant. Overall, the segment-counting method was determined as capable of predicting lung function after stapler-based thoracoscopic segmentectomy.

Disclosure Statement

None declared.

References

1) Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery, Shimizu H, et al. Thoracic and cardiovascular surgeries in Japan during 2017: annual report by the Japanese Association for Thoracic Surgery. Gen Thorac Cardiovasc Surg 2020; **68**: 414–9.
2) Suzuki K, Saji H, Aokage K, et al. Comparison of pulmonary segmentectomy and lobectomy: safety results of a randomized trial. J Thorac Cardiovasc Surg 2019; **158**: 895–907.
3) Gaidry AD, Tremblay L, Nakayama D, et al. The history of surgical staplers: a combination of Hungarian, Russian, and American innovation. Am Surg 2019; **85**: 563–6.
4) Molins L, Lanuti M, Force S, et al. Evaluation of a powered vascular stapler in video-assisted thoracic surgery lobectomy. J Surg Res 2020; **253**: 26–33.
5) Ohtsuka T, Goto T, Anraku M, et al. Dissection of lung parenchyma using electrocautery is a safe and acceptable method for anatomical sublobar resection. J Cardiothorac Surg 2012; **7**: 42.
6) Koike Y, Hattori A, Matsunaga T, et al. Postsurgical residual lung complications following left upper trisegmentectomy. Eur J Cardiothorac Surg 2020; **57**: 472–7.
7) Yano M, Iwata H, Hashizume M, et al. Adverse events of lung tissue stapling in thoracic surgery. Ann Thorac Cardiovasc Surg 2014; **20**: 370–7.
8) Ojanguren A, Gossot D, Seguin-Givelet A. Division of the intersegmental plane during thoracoscopic segmentectomy: is stapling an issue? J Thorac Dis 2016; **8**: 2158–64.
9) Tao H, Hayashi M, Furukawa M, et al. Influence of intersegmental plane size and segment division methods on preserved lung volume and function after pulmonary segmentectomy. Gen Thorac Cardiovasc Surg 2019; **67**: 234–8.
10) Juhl B, Frost N. A comparison between measured and calculated changes in the lung function after operation

for pulmonary cancer. Acta Anaesthesiol Scand Suppl 1975; **57**: 39–45.
11) Zeiher BG, Gross TJ, Kern JA, et al. Predicting postoperative pulmonary function in patients undergoing lung resection. Chest 1995; **108**: 68–72.
12) Yoshiyasu N, Kojima F, Takahashi O, et al. The impact of surgical chest wall damage caused by classic thoracotomy on pulmonary function and morphology. Gen Thorac Cardiovasc Surg 2020; **68**: 508–15.
13) Sato M, Omasa M, Chen F, et al. Use of virtual assisted lung mapping (VAL-MAP), a bronchoscopic multispot dye-marking technique using virtual images, for precise navigation of thoracoscopic sublobar lung resection. J Thorac Cardiovasc Surg 2014; **147**: 1813–9.
14) Saito H, Konno H, Atari M, et al. Management of intersegmental plane on pulmonary segmentectomy concerning postoperative complications. Ann Thorac Surg 2017; **103**: 1773–80.
15) Zhu Y, Pu Q, Liu C, et al. Trans-inferior-pulmonary-ligament single-direction thoracoscopic RS9 segmentectomy: application of stem-branch method for tracking anatomy. Ann Surg Oncol 2020; **27**: 3092–3.
16) Sato M, Murayama T, Nakajima J. Thoracoscopic stapler-based "bidirectional" segmentectomy for posterior basal segment (S10) and its variants. J Thorac Dis 2018; **10**: S1179–86.
17) Matsumoto M, Shirahashi K, Yamamoto H, et al. Division of the intersegmental plane using electrocautery for segmentectomy in clinical stage I non-small cell lung cancer. J Thorac Dis 2018; **10**: S1215–21.
18) Okada M, Tsutani Y, Ikeda T, et al. Radical hybrid video-assisted thoracic segmentectomy: long-term results of minimally invasive anatomical sublobar resection for treating lung cancer. Interact Cardiovasc Thorac Surg 2012; **14**: 5–11.
19) Sato M, Murayama T, Nakajima J. Techniques of stapler-based navigational thoracoscopic segmentectomy using virtual assisted lung mapping (VAL-MAP). J Thorac Dis 2016; **8**: S716–30.
20) Nomori H, Shiraishi A, Cong Y, et al. Differences in postoperative changes in pulmonary functions following segmentectomy compared with lobectomy. Eur J Cardiothorac Surg 2018; **53**: 640–7.
21) Tane S, Nishio W, Nishioka Y, et al. Evaluation of the residual lung function after thoracoscopic segmentectomy compared with lobectomy. Ann Thorac Surg 2019; **108**: 1543–50.
22) Nomori H, Shiraishi A, Yamazaki I, et al. Extent of segmentectomy that achieves greater lung preservation than lobectomy. Ann Thorac Surg Nov 20 2020 ahead of print.