The dynamic pulmonary functional change after thoracoscopic lower lobe segmentectomy

Kuroda, Sanae
Tane, Shinya
Kitamura, Yoshitaka
Maniwa, Yoshimasa
Nishio, Wataru

(Citation)
Asian Cardiovascular and Thoracic Annals,31(3):229-237

(Issue Date)
2023-03

(Resource Type)
journal article

(Version)
Accepted Manuscript

Abstract

Background: The advantages of segmentectomy over lobectomy in sparing pulmonary function remain controversial. Lower lobe segmentectomy is divided into simple segmentectomy, such as segment 6; and complex segmentectomy, which includes the basal segments. Here we compared residual lung function after thoracoscopic segmentectomy versus lobectomy in the lower lobe using the three-dimensional computed tomography volumetric method.

Methods: Between January 2012 and October 2020, 67 patients who underwent thoracoscopic segmentectomy of the lower lobe were matched to 67 patients who underwent thoracoscopic lower lobectomy during the same period using propensity score matching analysis. The postoperative decrease in the rate of forced expiratory volume in 1 s was compared between methods. The regional forced expiratory volume in 1 s of the residual lobe rescued by segmentectomy was measured using volumetric and spirometric analyses and compared to lower lobectomy. The ratio of the actual to predicted postoperative forced expiratory volume in 1 s in the residual lobe was defined as the preservation rate.

Results: Of the 67 thoracoscopic segmentectomies, 43 were S6, seven were S8, three were S8+9, seven were S10, and seven were S9+10. The percentage of postoperative/preoperative forced expiratory volume in 1 s was significantly higher in the segmentectomy versus lobectomy group (90.7% vs. 85.7%, p=0.001). The preservation rates after simple segmentectomy (n=43) and complex segmentectomy (n=24) did not differ significantly (82.2% vs. 80.2%, p=0.709).

Conclusions: Thoracoscopic lower lobe segmentectomy versus lobectomy preserves postoperative lung function. Even complex segmentectomy exhibited outcomes relevant to simple segmentectomy by sparing the residual lobe.

Keywords: Pulmonary function, video-assisted thoracic surgery (VATS), thoracic, lung, other

Introduction

While lobectomy has been accepted as a standard surgical treatment for peripheral small-sized non-small-cell lung cancer, segmentectomy has gained enthusiasm among thoracic surgeons for its ability to spare postoperative pulmonary function [1-3]. However, whether such limited resection can preserve pulmonary function compared with lobectomy remains controversial [4-6]. We previously reported that thoracoscopic segmentectomy is superior to thoracoscopic lobectomy for preserving pulmonary function using a three-dimensional (3D) volumetric method [7]. As the number and size of each segmentectomy type were too small in previous studies, the impact of the resected site on the extent of decreased pulmonary function has not been sufficiently investigated.

Lower lobe segmentectomy is roughly divided into two types: S6 and basal segment. S6 segmentectomy, considered among the most straightforward resections, is relatively easy and safe for thoracic surgeons with limited experience. Moreover, this procedure creates one linear intersegmental plane; therefore, it may be considered a “simple segmentectomy.” In contrast, basal segment segmentectomy, such as posterior basal segmentectomy, requires a deep anatomical understanding and surgical expertise. Furthermore, such a segmentectomy creates several intricate intersegmental planes and is thus considered a “complex segmentectomy.” Therefore, in terms of procedural complexity, basal segment segmentectomies differ completely from S6 segmentectomies. Although this procedural difference might affect postoperative functional changes, no comparative studies have examined the difference in postoperative pulmonary function between “simple” and “complex” thoracoscopic segmentectomies limited to the lower lobe.

Thus, this study aimed to demonstrate the superiority of segmentectomy over lobectomy for preserving pulmonary function with focus on the lower lobe and examine whether the procedural differences between "simple" and "complex" segmentectomies could influence the sparing of the postoperative lung function using a novel 3D volumetric method. We focused only on lower lobe segmentectomy in order to validate our technique for basal segment segmentectomies and its influence on postoperative pulmonary function.

Material and Methods

Ethical statement

The Hyogo Cancer Center Institutional Review Board (IRB) approved the study (IRB number: G-249; approved on February 2, 2022), and each participant provided informed consent.

Patient collection

We examined consecutive patients who underwent thoracoscopic lower segmentectomy at Hyogo Cancer Center between January 2012 and October 2020.

Using propensity score matching, 67 patients were paired with patients who underwent thoracoscopic lobectomy during the same period based on sex, smoking history, tumor location, and pulmonary function. The basic selection criteria for thoracoscopic segmentectomy included small peripheral non-small cell lung cancer with ground-glass opacity (indicating clinical T1a/1bN0M0 cancer based on the 8th edition of the Lung Cancer Stage Classification), compromised resection making patients poor candidates for lobectomy because of their limited cardiopulmonary function, and the presence of pulmonary metastases or benign lesions. Patients who had received induction therapy were excluded from the study.

We reviewed postoperative pulmonary complications, age, sex, smoking history, operative side, operation time, blood loss volume, forced expiratory volume in 1 s (FEV1.0), and forced vital capacity (FEV1.0/FVC) measured by spirometry. Operative mortality was defined as death within 30 days post-resection. Postoperative complications were defined as hypoxia requiring home oxygen therapy, pneumonia, prolonged air leakage that required adhesion therapy or lasted for more than 7 days, bronchopleural fistula (diagnosed by bronchoscopy or operative findings of leakage), empyema, atelectasis detected by chest radiography, uncontrolled sputum production that required bronchoscopy or tracheostomy, and acute exacerbation of idiopathic interstitial pneumonia.

Operative procedure

All segmentectomy and lobectomy procedures involved a 4-port thoracoscopic approach and were performed via 1–4-cm incisions without a rib spreader.

Representative images and movies are shown in Figure 1 and supplementary movie. First, we began by exposing the affected hilar structures, such as the segmental vessels and bronchus, which were dissected toward the periphery and subsequently severed. The intersegmental planes were identified using the inflation-deflation line method, with the systemic injection of indocyanine green (0.3 mg/kg) under a near-infrared thoracoscopic camera system (Visela Elite II; Olympus Co, Tokyo, Japan) being used to determine the demarcation line in some cases. The intersegmental planes were dissected using a staple device. To prevent prolonged air leakage, we used a bio-absorbable mesh (Neoveil; Gunze, Osaka, Japan) in combination with fibrin sealant (Beriplast; CSL Behring, Tokyo, Japan) immediately after intraoperative detection.

In terms of procedural difficulty, segmentectomy was categorized into simple and complex, specifically right or left S6 segmentectomy and resection of segments other than S6, respectively.

CT and 3D lung image construction

All plain chest CT examinations were performed using 16- or 80-multidetector row CT (MDCT) scanners (Aquilion 16 or Prime; Toshiba Medical Systems, Otawara, Japan). The entire lung was scanned from the lung apex to the diaphragm during a single breath hold at end inspiration. The scan parameters of the MDCT examination were as follows: 130 kVp and 150 mAs for collimation 1 mm × 16 and rotation, 0.5 s; 120 kVp and 390–500 mAs for collimation 0.5 mm × 80 and rotation, 0.35 s; 512 × 512 matrix; field of view, 320 mm; and reconstruction, 1 mm/1 mm.

Three-dimensional images were reconstructed from the CT data using SYNAPSE VINCENT 3D-CT rendering software (Fujifilm Corporation, Tokyo, Japan).

Image interpretation and data analysis

As shown in Figure 2 and described elsewhere [7], the regional FEV1.0 of the residual lobe rescued by segmentectomy was measured from the volumetric and spirometric parameters using the following formula:

FEV1.0 × (regional subjected lung volume/whole lung volume)

The predicted FEV1.0 of the lower residual segments to be preserved after segmentectomy was calculated using the following formula:

Preoperative FEV1.0 × (subjected lung volume/whole lung volume measured using preoperative 3D-CT)

Similarly, the actual FEV1.0 of the residual preserved lobe was calculated using the following equation:

Actual FEV1.0 × (subjected lung volume/whole lung volume measured using postoperative 3D-CT)

The ratio of the actual to predicted postoperative FEV1.0 in the residual lobe was defined as the preservation rate (%).

Statistical analysis

All statistical analyses were performed using JMP software (version 13; SAS Inc., Cary, NC, USA). All values are expressed as mean ± standard deviation. Because of the heterogeneity of the study cohorts, 1:1 propensity score matching was performed considering age, sex, lobectomy or segmentectomy, operation time, blood loss, smoking history, and preoperative FEV1.0. A two-tailed Student's t-test or the Mann-Whitney U test was used for the analysis.

The difference between the predicted and actual pulmonary functions of the residual preserved lobe in each segmentectomy group was analyzed using a paired t-test. Statistical significance was set at $p<0.05$.

Results

Operative results

Patient characteristics and results of the overall operation of the resected segment are summarized in Table 1. The average operation time and amount of bleeding were 190 ± 58 min and 47.9 ± 60.1 mL, in segmentectomy, and 180 ± 44 min and 74.6 ± 87.3 mL, in lobectomy cases, respectively. The amount of bleeding was significantly lower in the segmentectomy group than in the lobectomy group (p=0.041).

Regarding postoperative complications, among those who underwent segmentectomy, four patients presented with prolonged air leak, two with pneumonia, one with empyema, and one with atrial fibrillation. Among those who underwent lobectomy, four patients presented with prolonged air leak, one with empyema, and three with other symptoms. The complication rate was not significantly different between the two groups (p=1.000). No postoperative deaths occurred in either group.

Change in lung function

Figure 3a shows the changes in pulmonary function of the segmentectomy versus lobectomy groups. The percentages of postoperative/preoperative FEV1.0 were 90.7% and 85.7% for segmentectomy and lobectomy, respectively. Furthermore, the rate was higher in the lower segmentectomy group than in the lower lobectomy group (p=0.009). Figure 3b compares the percentage of postoperative/preoperative FEV1.0 between simple segmentectomy (such as segment 6), complex segmentectomy, and lobectomy. In the simple segmentectomy group, the percentage was 91.1%, whereas in the complex segmentectomy group, it was 90.0%. The percentages of postoperative/preoperative FEV1.0 did not differ significantly between S6 and complex segmentectomy (p=0.670).

Comparison of “complex” and “simple” segmentectomy

Figure 4 shows the predicted and actual residual lobe volumes in S6 and complex segmentectomy. No significant difference was observed between the predicted and actual residual lobe volumes (S6, p=0.191; complex, p=0.115). The preservation rate of the residual lobe was 82.2% ± 21.0% in S6, 90.8% ± 23.0% in S8, 86.9% ± 11.9% in S8+9, 76.9% ± 21.1% in S10, and 70.1% ± 12.7% in S9+10. Figure 5 compares the preservation rates between S6 and complex segmentectomies, showing a non-significant difference (p=0.756) for S6 and complex segmentectomy (82.2% and 80.2%, respectively).

To further investigate whether preoperative pulmonary function may affect surgical outcomes and pulmonary functional changes, we divided the patients who underwent segmentectomy into two groups (COPD group: FEV1.0/FVC < 70%; non-COPD group: FEV1.0/FVC ≥ 70%). The rate of postoperative complications was non-significantly higher in the COPD group than in the non-COPD group (21.1% vs. 8.3%; p=0.152) (Table 2). Pulmonary functional changes, such as the percentage of postoperative/preoperative FEV1.0 and the preservation rate of the residual lobe, were not significantly different irrespective of preoperative pulmonary function (p=0.152 and p=0.243, respectively).

Discussion

Segmentectomy has evolved to offer better postoperative pulmonary function than lobectomy in cases of peripheral small non-small-cell lung cancer. Although several researchers have demonstrated and validated its functional benefit, some issues remain to be addressed, including the evaluated time point (short- or long-term after surgery), whether patients with impaired pulmonary function can benefit from this procedure, and whether the thoracoscopic approach may preserve pulmonary function better than thoracotomy [8]. Moreover, it remains unclear whether the segmentectomy site could affect the postoperative functional change; that is, whether anatomical repositioning of the ipsilateral preserved lobes after resection could influence postoperative lung function. To date, no studies have focused on the postoperative functional changes in thoracoscopic segmentectomy limited to the lower lobe.

The utilization of 3D-CT is a game-changer in the field of general thoracic surgery because it enables the identification of the vasculature and surgical margin from the tumor before lung resection [9,10]. It can also be applied to other analyses, including calculations of lung volume, as well as quantitative and morphological assessment of emphysema as demonstrated previously [11]. Using this cutting-edge 3D reconstruction software, we investigated the postoperative functional difference between thoracoscopic segmentectomy and lobectomy in the lower lobe and examined whether segmentectomy type could affect the dynamic change in the residual lobe.

While S6 segmentectomy is technically simple, basal segment segmentectomy, particularly dorsal basal segmentectomy, is challenging owing to its technical complexity. In the current study, we safely performed 14 dorsal basal segmentectomy procedures through a unique posterior approach in which the parenchyma between segments S6 and S10 was divided along V6 from the dorsal side of the lower lobe [12,13]. This procedure can expose the targeted bronchus and artery from the posterior side, avoiding unnecessary parenchymal splitting from the major fissure. Thus, to validate our technique for basal segment segmentectomy and its influence on postoperative pulmonary function, we focused only on lower lobe segmentectomy, and compared lower lobe simple and complex segmentectomies. As a result, despite the difference in procedural difficulty among segmentectomy types, the preservation rate of the residual lobe in these procedures did not differ in the current study, demonstrating that thoracoscopic complex segmentectomy is feasible since it spares postoperative lung function.

Next, the surgical outcomes of complex segmentectomy should be considered. Handa et al. reported that complex segmentectomy did not increase the postoperative complications rate compared with simple segmentectomy [14]. This is consistent with the findings of the current study, which showed that simple and complex segmentectomies of the lower lobe yielded comparable surgical outcomes to those of lower lobectomy. However, we should keep in mind that the patients with COPD exhibited the higher rate of postoperative complication than that with non-COPD. The optimization with the use of preoperative inhaled bronchodilator and pulmonary rehabilitation may prevent postoperative complications in the patients with COPD [15, 16]. Prolonged air leak after complex segmentectomy should also be noted, particularly in the patients with COPD, and no effort should be expended during the operation to prevent postoperative air leaks. Concretely speaking, fistulae of the bronchioles that found during the water-sealing test should be sutured thoroughly. Moreover, we usually consider that mechanical stapling line cutting for the intersegmental plane should be performed in line to minimize the number of junctional points, which helps avoid postoperative air leaks.

The preservation rate of the residual lobe was lower than that expected preoperatively for all segmentectomy types. One reason for this is that the intersegmental plane was dissected by staplers, which disturbed the inflation of the residual lobe. Ohtsuka et al. demonstrated that cutting the intersegmental plane with electrocautery could achieve meticulous division of the intersegmental plane and maintain the shape of the residual segments, leading to better preservation of postoperative pulmonary function than with staplers [17]. However, the drawback of this procedure is prolonged air leaks. Pleural sutures or closure of residual segments should be considered to prevent extended air leakage.

The present study has several limitations. First, it was a non-randomized retrospective single-institution study. Despite the propensity score matching and performance of all procedures uniformly through a thoracoscopic approach, this study design is associated with patient selection and other biases. Second, we examined postoperative pulmonary function only by calculating lung volume without evaluating perfusion of the residual lungs. Additional modalities such as lung perfusion single-photon emission CT should be considered. Third, postoperative spirometry was performed at 6 months post-resection. Several time-point evaluations, such as the 1-year evaluation after lung resection, should be performed to elucidate the chronological functional changes that occur after resection.

Using the cutting-edge 3D-CT volumetric method, we confirmed that thoracoscopic segmentectomy in the lower lobe helps better preserve postoperative pulmonary function than thoracoscopic lobectomy. Moreover, complex segmentectomy yields a comparable effect to simple segmentectomy in terms of retaining the residual lobe rescued by segmentectomy, indicating that our thoracoscopic segmentectomy method could contribute to the maintenance of postoperative pulmonary function, even in cases of complex segmentectomy.

Funding: None declared.

Conflict of interest: None declared.

Ethical approval: G-249. February, 2, 2022.

Informed Consent: None declared.

Acknowledgements: The authors would like to thank Editage (www.editage.com) for English language editing.

Author contribution statement:

Sanae Kuroda: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration

Shinya Tane: Validation; Visualization; Writing-original draft; Writing-review and editing

Yoshitaka Kitamura: Writing-review and editing

Yoshimasa Maniwa: Writing-review and editing

Wataru Nishio: Writing-review and editing; Supervision

References

1. Okada M, Yoshikawa K, Hatta T, Tsubota N. Is segmentectomy with lymph node assessment an alternative to lobectomy for non-small cell lung cancer of 2 cm or smaller? Ann Thorac Surg 2001;71:956-960.
2. Ginsberg RJ, Rubinstein LV. Randomized trial of lobectomy versus limited resection for T1 N0 non-small cell lung cancer. Lung Cancer Study Group. Ann Thorac Surg 1995;60:615- 622.
3. Saji H, Okada M, Tsuboi M, Nakajima R, Suzuki K, et al. Segmentectomy versus lobectomy in small-sized peripheral non-small-cell lung cancer (JCOG0802/WJOG4607L): a multicentre, open-label, phase 3, randomised, controlled, non-inferiority trial. Lancet 2022;399:1607-1617.
4. Harada H, Okada M, Sakamoto T, Matsuoka H, Tsubota N. Functional advantage after radical segmentectomy versus lobectomy for lung cancer. Ann Thorac Surg 2005;80:2041-2045.
5. Ueda K, Tanaka T, Hayashi M, Li TS, Tanaka N, Hamano K. Computed tomography- defined functional lung volume after segmentectomy versus lobectomy. Eur J Cardiothorac Surg 2010;37:1433-1437.
6. Nomori H, Shiraishi A, Cong Y, Sugimura H, Mishima S. Differences in postoperative changes in pulmonary functions following segmentectomy compared with lobectomy. Eur J Cardiothorac Surg 2018;53:640-647.
7. Tane S, Nishio W, Nishioka Y, Tanaka H, Ogawa H, Kitamura Y, Takenaka D, Yoshimura M. Evaluation of the Residual Lung Function After Thoracoscopic Segmentectomy Compared With Lobectomy. Ann Thorac Surg 2019;108:1543-1550.

8. Charloux A, Quoix E. Lung segmentectomy: does it offer a real functional benefit over lobectomy? Eur Respir Rev 2017;26

9. Saji H, Inoue T, Kato Y, Shimada Y, Hagiwara M, Kudo Y, Akata S, Ikeda N. Virtual segmentectomy based on high-quality three-dimensional lung modelling from computed tomography images. Interact Cardiovasc Thorac Surg 2013;17:227-232.

10. Chan EG, Landreneau JR, Schuchert MJ, Odell DD, Gu S, Pu J, Luketich JD, Landreneau RJ. Preoperative (3-dimensional) computed tomography lung reconstruction before anatomic segmentectomy or lobectomy for stage I non-small cell lung cancer. J Thorac Cardiovasc Surg 2015;150:523-528.

11. Tane S, Nishikubo M, Kitazume M, Fujibayashi Y, Kimura K, Kitamura Y, Takenaka D, Nishio W. Cluster analysis of emphysema for predicting pulmonary complications after thoracoscopic lobectomy. Eur J Cardiothorac Surg 2021;60:607-613.

12. Endoh M, Oizumi H, Kato H, Suzuki J, Watarai H, Masaoka T, Sadahiro M. Posterior approach to thoracoscopic pulmonary segmentectomy of the dorsal basal segment: A single-institute retrospective review. J Thorac Cardiovasc Surg 2017;154:1432-1439.

13. Nishio W, Tane K, Uchino K, Yoshimura M. Total thoracoscopic posterior basal segmentectomy for primary lung cancer. Multimedia manual of cardiothoracic surgery : MMCTS / European Association for Cardio-Thoracic Surgery 2014.

14. Handa Y, Tsutani Y, Mimae T, Tasaki T, Miyata Y, Okada M. Surgical Outcomes of Complex Versus Simple Segmentectomy for Stage I Non-Small Cell Lung Cancer. Ann Thorac Surg 2019;107:1032-1039.

15. Makino T, Otsuka H, Hata Y, Koezuka S, Azuma Y, Isobe K, Sugino K, Ebihara S, Homma S, Iyoda A. Long-acting muscarinic antagonist and long-acting β2-agonist therapy to optimize chronic obstructive pulmonary disease prior to lung cancer surgery. Mol Clin Oncol 2018;8(5):647-652.

16. Saito T, Ono R, Tanaka Y, Tatebayashi D, Okumura M, Makiura D, Inoue J, Fijikawa T, Kondo S, Inoue T, Maniwa Y, Sakai Y. The effect of home-based preoperative pulmonary rehabilitation before lung resection: A retrospective cohort study. Lung Cancer;162:135-139.

17. Ohtsuka T, Goto T, Anraku M, Kohno M, Izumi Y, Horinouchi H, Nomori H. Dissection of lung parenchyma using electrocautery is a safe and acceptable method for anatomical sublobar resection. J Cardiothorac Surg 2012;7**:**42.

Table 1,

Table 1. Patients Characteristics After Propensity Score Matching

Characteristics	Segmentectomy (n = 67)	Lobectomy (n = 67)	P value
Age,y	69.5	69.4	0.928
Gender			0.594
Male	44	41	
Female	23	26	
Smoking History (PY)	28.6	23.6	0.373
Diagnosis			0.049
Lung Cancer	57	64	
Metastases	7	2	
Malignant lymphoma	0	1	
Benign diseases	3	0	
Preoperative FEV1.0/FVC, %	73.7	73.7	0.995
Preoperative FEV1.0, L	2.23 ± 0.68	2.31 ± 0.66	0.478
Postoperative FEV1.0, L	2.02 ± 0.63	1.98 ± 0.61	0.704
Resected location			0.035
Right	34	46	
S6	22		
S8	4		
S8+9	3		
S10	2		
S9+10	3		
Left	33	21	
S6	21		
S8	3		
S8+9	0		
S10	5		
S9+10	4		
Operating time, min	190 ± 58	180 ± 44	0.250
Blood loss, mL	47.9 ± 60.1	74.6 ± 87.2	0.041

Postoperative complications	8 (11.9)	9 (13.4)	0.797
Prolonged air leak *	4	4	
Pneumonia	2	0	
Empyema	1	1	
Interstitial pneumonia	0	1	
Atrial fibrillation	1	2	
Cerebral infarction	0	1	

*Prolonged air leak was defined as air leak lasting longer than 7 days or the use of pleurodesis.

Value are n, mean ± SD, or n (%)

FEV1.0, forced expiratory volume in 1 second.

PY, pack-year.

Table 2,

Table 2. Comparison of patient characteristics and perioperative outcomes between COPD and non-COPD patients who underwent segmentectomy.

Characteristics	COPD FEV1.0/FVC < 70% (n= 19)	non-COPD FEV1.0/FVC ≥ 70% (n = 48)	P-value
Age,y	68.7	71.7	0.228
Gender			0.009
Male	17	27	
Female	2	21	
Smoking History (PY)	49.1	20.4	0.002
Postoperative complications	4 (21.1)	4 (8.3)	0.152
Prolonged air leak *	0	4	
Pneumonia	2	0	
Empyema	1	0	
Atrial fibrillation	1	0	

*Prolonged air leak was defined as air leak lasting longer than 7 days or the use of pleurodesis.

Value are n, mean ± SD, or n (%)

FEV1.0, forced expiratory volume in 1 second.

FVC, forced vital capacity.

PY, pack-year.

Figure legends

Figure 1,

A representative case of thoracoscopic left S10 segmentecomy.

A, Computed tomography findings showing a solid nodule (yellow arrow) in the left S10c.

B, Three-dimensional vasculature image and visual guidance of virtual S10 segmentectomy produced by the Synapse Vincent.

C, After ligation of the segmental artery, vein, and bronchus, the intersegmental plane was identified using a systemic indocyanine green injection.

D, Operative view after S10 segmentectomy. The intersegmental plane was dissected to preserve the intersegmental veins.

Figure 2,

The regional FEV1.0 of the residual lobe rescued by segmentectomy was measured from the volumetric and spirometric parameters.

Figure 3,

Comparison of the percentage of postoperative/preoperative of FEV1.0 (A) between segmentectomy and lobectomy in the lower lobe, and (B) simple, complex segmentectomy, and lobectomy.

Figure 4,

The change in the left upper residual lobe volume before and after simple (S6) and complex (S10) segmentectomy (A, C). There were no significant differences in predicted and actual residual lobe volume (S6; p=0.191, complex; p=0.115) (B, D).

Figure 5,

Comparison of the preservation rate of the residual lobe between simple (S6) and complex segmentectomies. The preservation rate was not significant different in simple and complex segmentectomies (p=0.71).

Figure 1

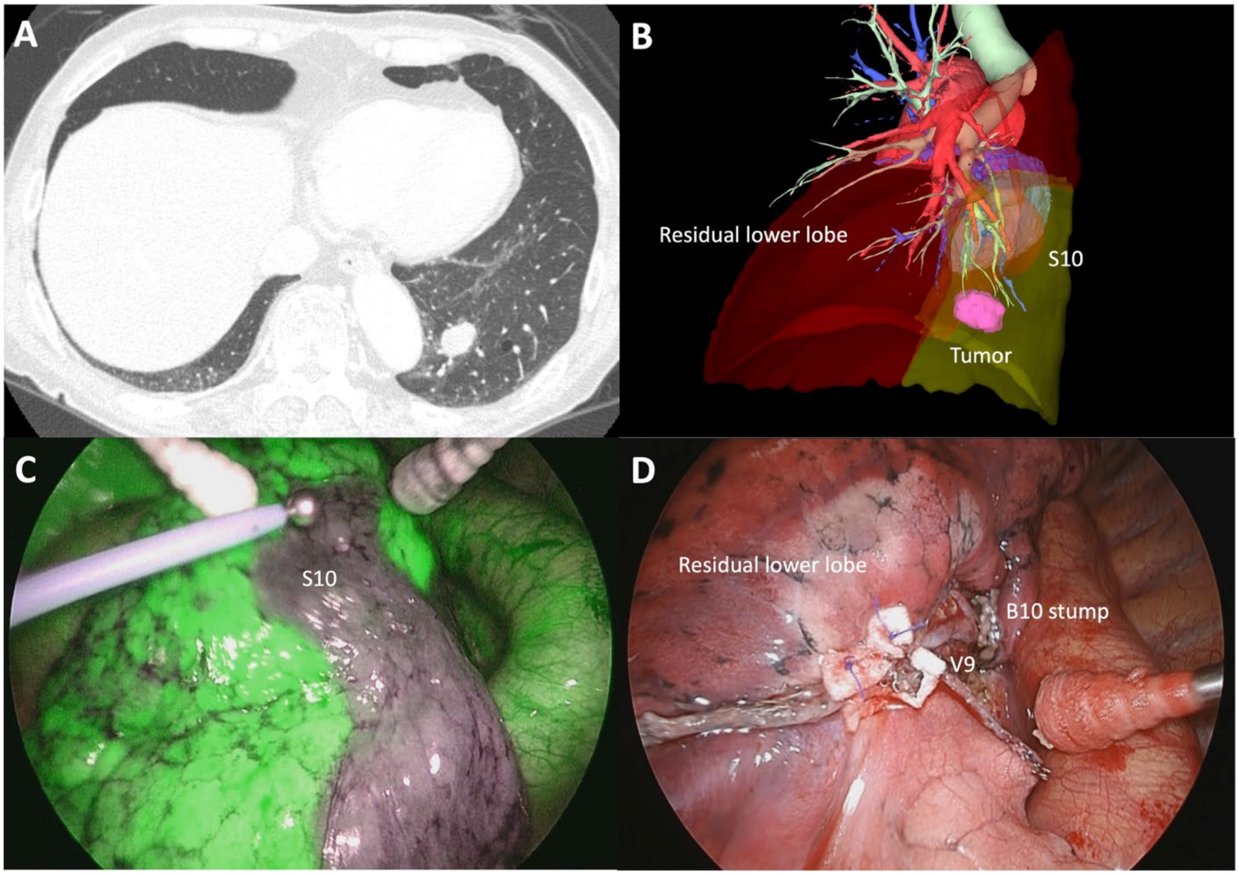

A
B
Residual lower lobe
S10
Tumor
C
S10
D
Residual lower lobe
B10 stump
V9

Figure 2

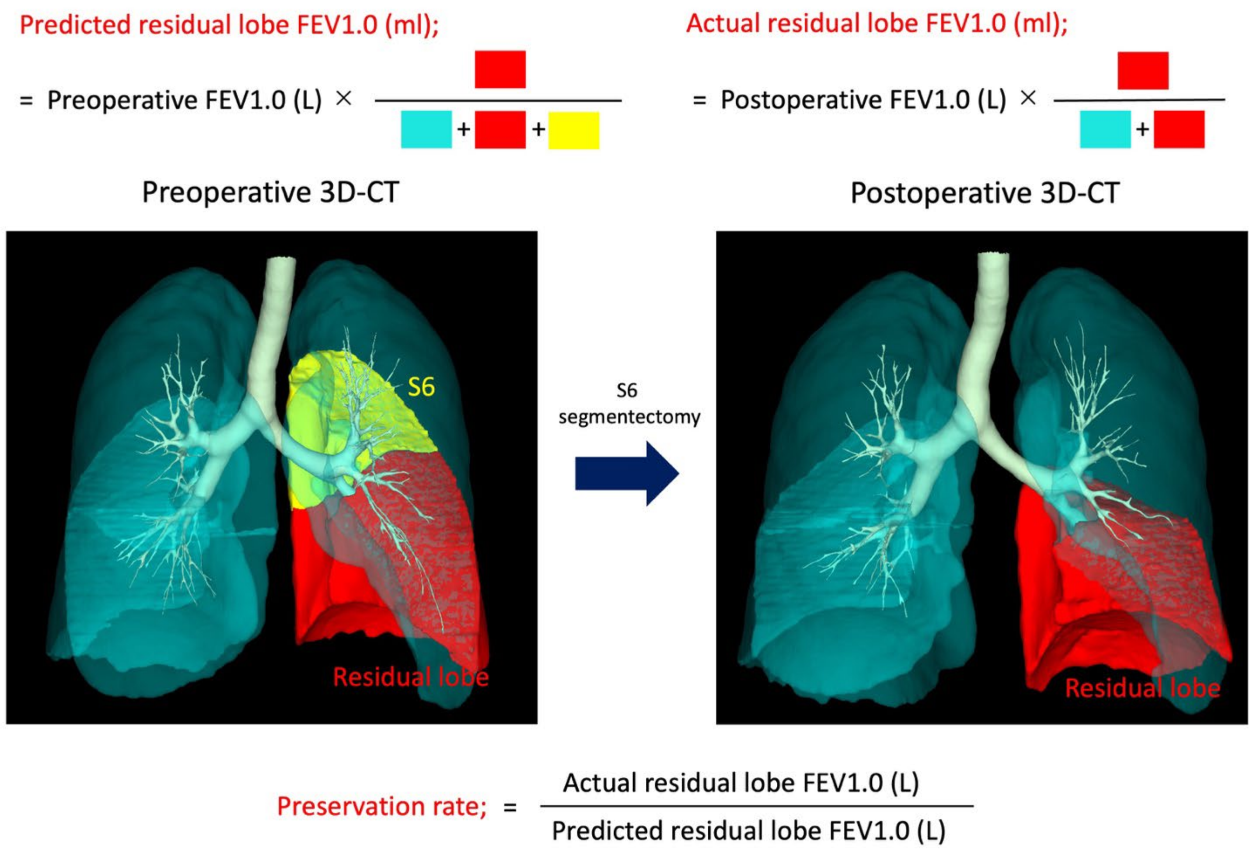
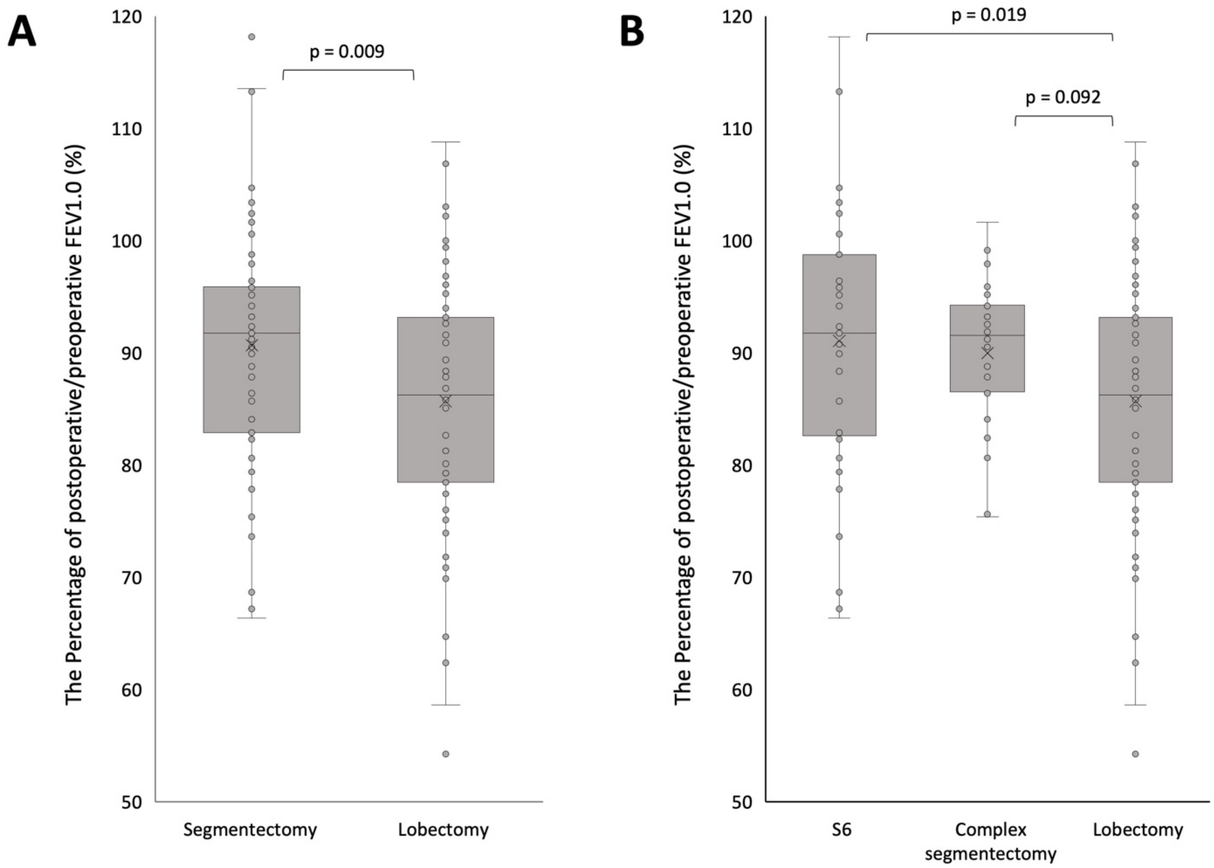
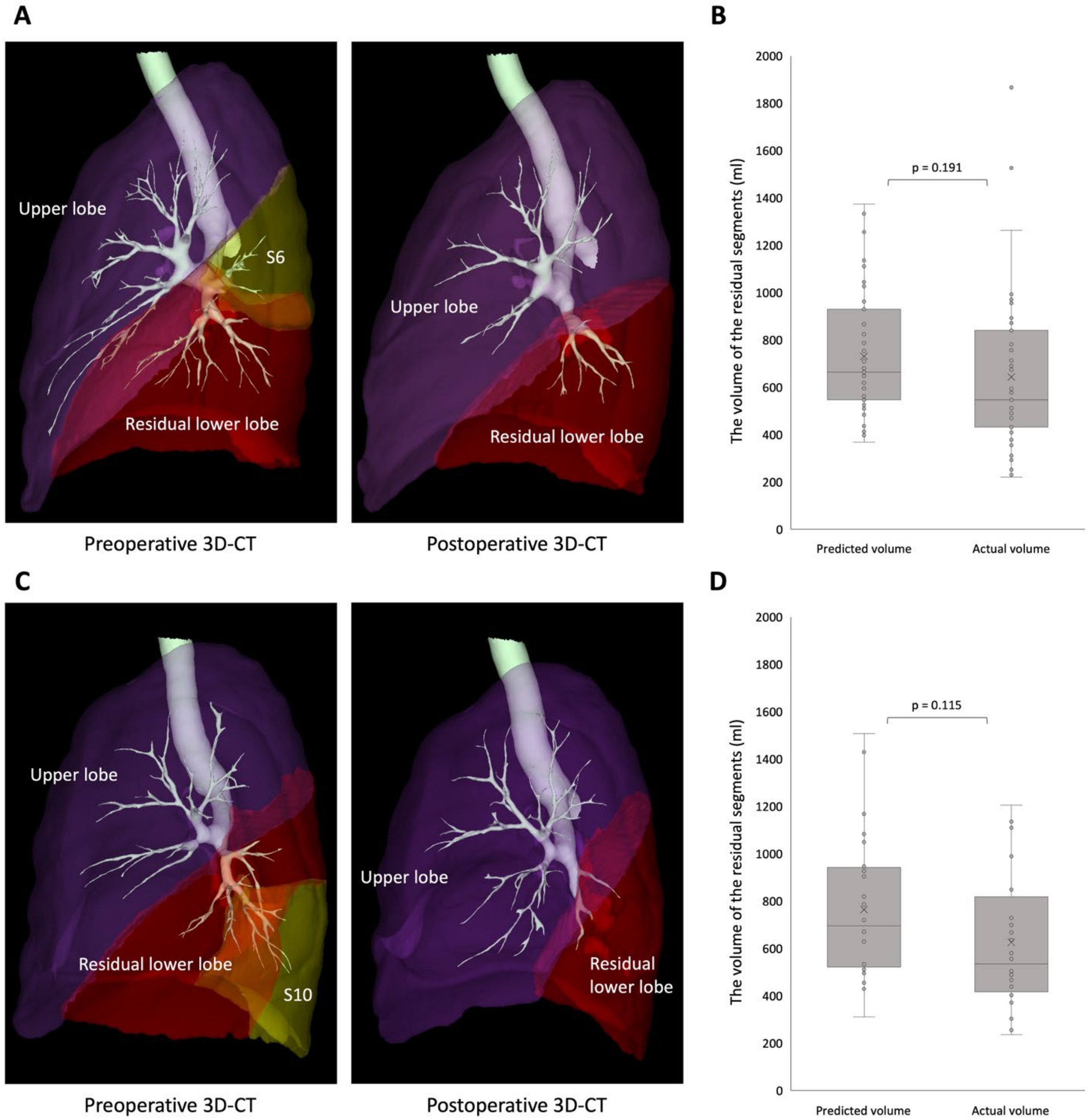

Predicted residual lobe FEV1.0 (ml);
= Preoperative FEV1.0 (L) ×
+
+
Actual residual lobe FEV1.0 (ml);
= Postoperative FEV1.0 (L) ×
+
Preoperative 3D-CT
Postoperative 3D-CT
S6
S6
segmentectomy
Residual lobe
Residual lobe
Preservation rate; =
Actual residual lobe FEV1.0 (L)
Predicted residual lobe FEV1.0 (L)

Figure 3

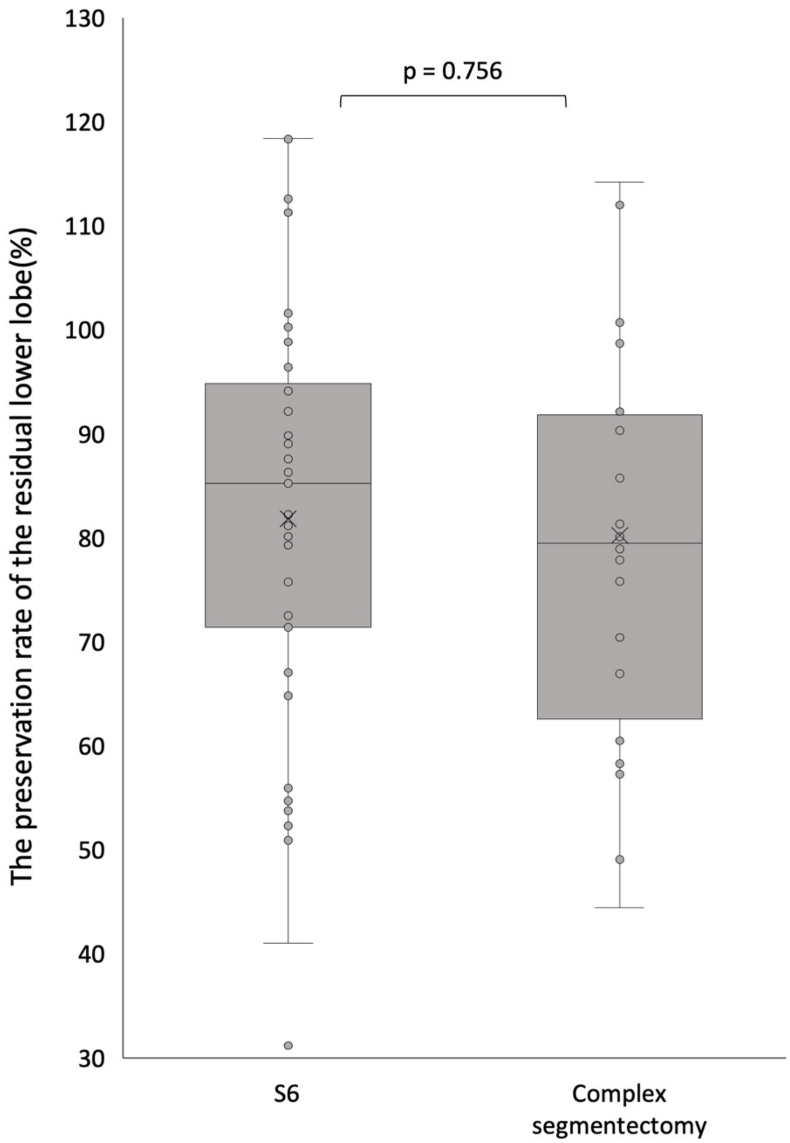


A
B
p = 0.009
p = 0.019
p = 0.092
The Percentage of postoperative/preoperative FEV1.0 (%)
120
110
100
90
80
70
60
50
Segmentectomy
Lobectomy
S6
Complex segmentectomy

Figure 4


A
B
C
D
Upper lobe
S6
Residual lower lobe
Preoperative 3D-CT
Postoperative 3D-CT
The volume of the residual segments (ml)
p = 0.191
Predicted volume
Actual volume
S10
Residual
lower lobe
p = 0.115
0
200
400
600
800
1000
1200
1400
1600
1800
2000

1 **Figure 5**


p = 0.756
130
120
110
100
90
80
70
60
50
40
30
The preservation rate of the residual lower lobe(%)
S6
Complex segmentectomy