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Pulmonary function changes after uniportal video-assisted thoracoscopic anatomical lung resection

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***Abstract*---**Background: Some early staged NSCLC appears as non-subpleural peripheral pulmonary nodules. Thoracic surgeons usually adopt extended wedge resection or segmentectomy to remove these nodules. Video-assisted thoracoscopic surgery (VATS) has been carried out extensively worldwide in lung surgeries. The purpose of this study was to evaluate changes in postoperative pulmonary function changes after undergoing VATS wedge resection and VATS segmentectomy anatomical lung resection. Methods: This retrospective study was carried out on 80 patients scheduled for UVATS sublobar resection lung surgery. Patients were divided equally into two groups according to the surgical procedures, VATS wedge resection group, and VATS segmentectomy group. All patients were subjected to full history taking length of stapler on CT scan, preoperative and postoperative pulmonary function tests include Forced vital capacity (FVC), Forced expiratory volume (FEV1), FEV1/FVC ratio, operation characteristics, postoperative recovery, treatment and hospitalization expenses. Results: FVC loss after segmentectomy was significantly greater than after wedge resection (17.1 ± 1.58%, vs. 7.9 ± 1.59% $P < 0.001$). Preoperative pulmonary function (FEV1 and FVC) was statistically different between the two groups of patients. Postoperative pulmonary function (FEV1, FVC and FEV1/-FVC) was statistically different between the two groups of patients. Linear regression showed that the change of preoperative pulmonary function was not able to trigger the change of FVC loss.

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Conclusions: Wedge resection seemed to have more advantages in preserving patients' FVC and MVV. Wedge resection also showed recognized ability in other aspects. VATS wedge resection for peripheral non-subpleural nodules were not inferior to that of VATS segmentectomy.

***Keywords*---**Pulmonary Function, Uniportal, Video-assisted thoracoscopic, Lung Resection.

Introduction

Surgeons are constantly improving their surgical techniques to achieve positive outcomes in minimally invasive thoracic surgery, where the aim is completing surgical operations with minimal trauma. [1] With the progress of imaging technology, especially the application of CT, more and more early staged lung cancer has been detected. Some early-staged NSCLC appears as non-subpleural peripheral pulmonary nodules. Thoracic surgeons usually adopt extended wedge resection or segmentectomy to remove these nodules. [2, 3]

However, segmentectomy is technically more demanding than wedge resection because the surgeon will have to carefully identify segmental pulmonary vessels and bronchi. [4] Moreover, segmentectomy has more concerns about the extension of operation time and postoperative air leak time, and so on. Various reasons mentioned above have limited the promotion of segmentectomy, and the impact of segmentectomy on postoperative pulmonary function is controversial. [5]

Video-assisted thoracoscopic surgery (VATS) has been carried out extensively worldwide, and traditional thoracotomy can be avoided in almost all lung surgeries. [6] When VATS is performed with minimal invasion in the thoracic wall, avoiding the severe neuromuscular trauma associated with traditional thoracotomy, this can significantly enhance the speed of recovery, improve the patient's postoperative quality of life, and reduce postoperative complications. [7] The advantages of VATS include less postoperative pain and shorter hospital stay for patients compared to thoracotomy, and this approach is recommended as the standard treatment method for clinical stage I non-small cell lung cancer (NSCLC) by the American College of Chest Physicians and the National Comprehensive Cancer Network. [8]

Recently, the VATS technique has been further developed and uniportal VATS (U-VATS) anatomical lung resection has become increasingly popular worldwide. U-VATS was first introduced and applied to anatomical lung resection 10 years ago; however, its potential advantages over other VATS techniques remain controversial. [9, 10]

The indications of UVATS anatomical lung resection have also been expanded as well as early-stage NSCLC. [11] Large studies have so far reported low complication rates and encouraging outcomes in patients in which uniportal VATS has been used. [12] Although UVATS anatomical lung resection has become more widely accepted, mid- or long-term oncological outcomes are lacking. [13]

The purpose of this study was to evaluate changes in postoperative pulmonary function changes after undergoing VATS wedge resection and VATS segmentectomy anatomical lung resection.

Materials and Methods

This retrospective study was carried out on 80 patients aged greater than or equal to 18 years old, both sexes, scheduled for UVATS sublobar resection lung surgery. An informed written consent was obtained from the patient or relatives of the patients. The study was during the period from January 2018 to August 2021 after approval from the Ethical Committee XXXX University Hospitals.

Inclusion criteria were patients with peripheral nodules, patients performed of VATS sublobar resection (wedge resection, segmentectomy) under uniportal VATS. The preoperative pulmonary function of all included patients was tolerable to lobectomy.

Exclusion criteria were incomplete perioperative data, patients with subpleural nodules (nodule is not further than 10 mm from the pleura), patients who received radiotherapy and chemotherapy before or after operation, patients confirmed serious heart, brain, and liver comorbidities, or other serious diseases; COPD (Chronic Obstructive Pulmonary Disease), asthma, bronchiectasis, and pulmonary infection before operation. patients with relative contraindications of pulmonary function test, like acute myocardial infarction within 1 week, or history of neurosurgery within 4 weeks, patients with severe postoperative complications, and patients with extensive pleural adhesion confirmed during operation, which may affect the preoperative pulmonary function.

Patients were divided equally into two groups according to the surgical procedures, VATS wedge resection group, and VATS segmentectomy group. All patients were subjected to full history taking; patient age, sex, smoking history, pathological types, distance from nodule to pleura, length of stapler on CT scan (3 months after surgery), preoperative and postoperative pulmonary function tests (PFTs) includes Forced vital capacity (FVC), Forced expiratory volume(FEV1), FEV1/FVC ratio, operation characteristics (operating time, intraoperative blood loss), postoperative recovery (chest drainage, postoperative complications, air leak time, hospital stay), treatment and hospitalization expenses.

All patients were performed a single incision whose size was 3–6 cm in the fourth or fifth intercostal space of the anterior axillary line. The surgical procedure was decided according to the preoperative imaging data, intraoperative rapid pathology, and operation difficulty, surgeon's habits or so on.

Surgical technique

Patient position in lateral position, healthy side down under general anesthesia, double-cavity endotracheal intubation, single-lung ventilation.

Segmentectomy's procedure

All patients underwent chest CT scan after admission. We used Exoview system to make preoperative 3D reconstruction. Then we used ICG (indocyanine green) fluorescence method to identify the IBL (intersegmental boundary line) and perform anatomical segmentectomy. Next, leakage test was performed. If significant air leakage is found, 4-0 Prolene suture was used for repair. Lymph nodes were grouped and resected or sampled according to the Chinese guidelines for the diagnosis and treatment of primary lung cancer [14]. A 28-F chest drainage tube was placed at the surgical port after surgery.

Wedge resection's procedure

Preoperative preparation was not significantly different from segmentectomy. According to the needs of the operation, CT guided localization may be performed 30 min before the operation in order to achieve accurate resection. Wedge resection was performed using staplers. Margins were confirmed intraoperatively, most cases obtained a sufficient resection margin, and additional resection were added if margin was not enough. The patient was placed a chest tube postoperatively, then returned to the ward.

Every operation we performed the resection of tumor according to the principles of oncology, the length of the resection margins was guaranteed to be greater than the tumor diameter or greater than 2 cm, and all samples were sent for rapid frozen section to clarify the pathology and ensure negative margins. Patients included in this study all had complete tumor resection with negative margins.

Postoperative management

All patients returned to the thoracic ward after surgery. Patients were guided to make breathing exercises, and encouraged to ambulate, to reduce the post-operative complications, thus discharge early and improve pulmonary function and QOL (quality of life). Patients whose chest tube drainage was less than 200 mL/day, radiograph confirmed no pneumothorax, and cough without air leak were allowed to remove their chest tube.

Sample Size Calculation

The sample size calculation was done by G*Power 3.1.9.2 (Universität Kiel, Germany) that the sample size was based on the following considerations: the mean (± SD) of FEV1 loss between these two groups (17.6±2.1%, wedge resection vs. 19.4±5.4%, segmentectomy, 0.99 effect size, 95% confidence limit, 90% power of the study, and 5 cases were added to each group to overcome dropout. Therefore, we recruited 40 patients in each group.

Statistical analysis

Statistical analysis was done by SPSS v27 (IBM©, Armonk, NY, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative parametric data were presented as mean and standard deviation (SD) and were analyzed by unpaired student t-test. Quantitative non-parametric data were analyzed by Mann Whitney-test. Qualitative variables were presented as frequency and percentage (%) and analyzed using the Chi-square test or Fisher's exact test when appropriate. Linear regression is also used to estimate the relationship between a dependent variable and one or more independent variables. A two-tailed P value < 0.05 was considered statistically significant.

Results

Demographic data (age, sex, weight, height and BMI) and comorbidities (HTN, DM and smoking) were insignificantly different between the studied groups. Table 1

Table 1: Demographic data of the studied groups

		Wedge resection group (n = 40)	Segmentectomy group (n = 40)	P value
Age (years)		41.05 ± 11.81	41.13 ± 12.68	0.978
Sex	Male	15 (37.5%)	18 (45%)	0.649
	Female	25 (62.5%)	22 (55%)	
Weight (Kg)		67.2 ± 6.66	68.1 ± 8.51	0.600
Height (m)		1.63 ± 0.04	1.62 ± 0.05	0.925
BMI (kg/m^2)		25.9 ± 3.18	25.8 ± 3.86	0.865
HTN		10 (25%)	13 (32.5%)	0.621
DM		12 (30%)	8 (20%)	0.438
Smoking		5 (12.5%)	6 (15%)	0.745

Data are presented as mean ± SD or frequency (%). BMI: Body mass index, HTN: hypertension, DM: diabetes mellitus.

In segmentectomy group, target lung segment was S ^{1} in 6 (15%) patients, S $^{1+2}$ in12 (30%) patients, S $^{4+5}$ in 3 (7.5%) patients, S ^{6} in 9 (22.5%) patients and S $^{9+10}$ in 10 (25%) patients. Wedge resection group had distance from nodule to pleura (24.4 ± 3.16 mm vs. 28.6 ± 5.53 mm, P <0.001), a shorter duration of surgery (69.8 ± 12.72 min vs. 104.5 ± 27.71min, P <0.001), less postoperative drainage (87.2 ± 28.15mL vs. 246.3 ± 365.94 mL, P=0.008) and shorter hospital stay time (2.8 ± 0.8 days vs. 3.3 ± 1.09 days, P=0.049). Length of stapler trace on chest CT 3 months after operation was measured for each patient **(**Figure 1) and was significantly lower in wedge resection group compared to segmental resection group (16.1 ± 4.35 mm, vs. 24.2 ± 6.92 mm, P < 0.001). The number of staplers used in was also significantly higher in segmental resection group than that in wedge resection group (2.4 ± 0.44, vs. 5.1 ± 0.82, P < 0.001). Preoperative imaging diagnosis, intraoperative frozen section, tumour diameter and air leak time were insignificantly different between the studied groups. Table 2

Table 2: Clinical data of the studied groups

		Wedge resection group (n = 40)	Segmentectomy group (n = 40)	P value
Preoperative imaging diagnosis	Pure GGN	22 (55%)	26 (65%)	0.493
	Mixed GGN	18 (45%)	14 (35%)	
Target lung segment	S^{1}	---	6 (15%)	---
	S^{1+2}	---	12 (30%)	
	S^{4+5}	---	3 (7.5%)	
	S^{6}	---	9 (22.5%)	
	S^{9+10}	---	10 (25%)	
Intraoperative frozen section	AHH	0 (0%)	0 (0%)	0.606
	AIS	25 (62.5%)	19 (47.5%)	
	MIA	6 (15%)	7 (17.5%)	
	IAC	0 (0%)	0 (0%)	
	Benign lesion	8 (20%)	10 (25%)	
Tumor diameter		11.5 ± 1.88	10.6 ± 2.99	0.120
Distance from nodule to pleura (mm)		24.4 ± 3.16	28.6 ± 5.53	**<0.001***
Duration of surgery (min)		69.8 ± 12.72	104.5 ± 27.71	**<0.001***
Postoperative drainage (mL)		87.2 ± 28.15	246.3 ± 365.94	**0.008***
Air leak time (days)		1.9 ± 0.83	2.3 ± 1.19	0.100
Hospital stay (days)		2.8 ± 0.8	3.3 ± 1.09	**0.049***
Length of staplers (mm)		16.1 ± 4.35	24.2 ± 6.92	**<0.001***
No of staplers		2.4 ± 0.44	5.1 ± 0.82	**<0.001***

Data are presented as mean ± SD or frequency (%). GGN: ground-glass nodule, AHH atypical adenomatous hyperplasia, AIS adenocarcinoma in situ, MIA minimally invasive adenocarcinoma, IAC invasive adenocarcinoma cancer, *: statistically significant as P value <0.05.

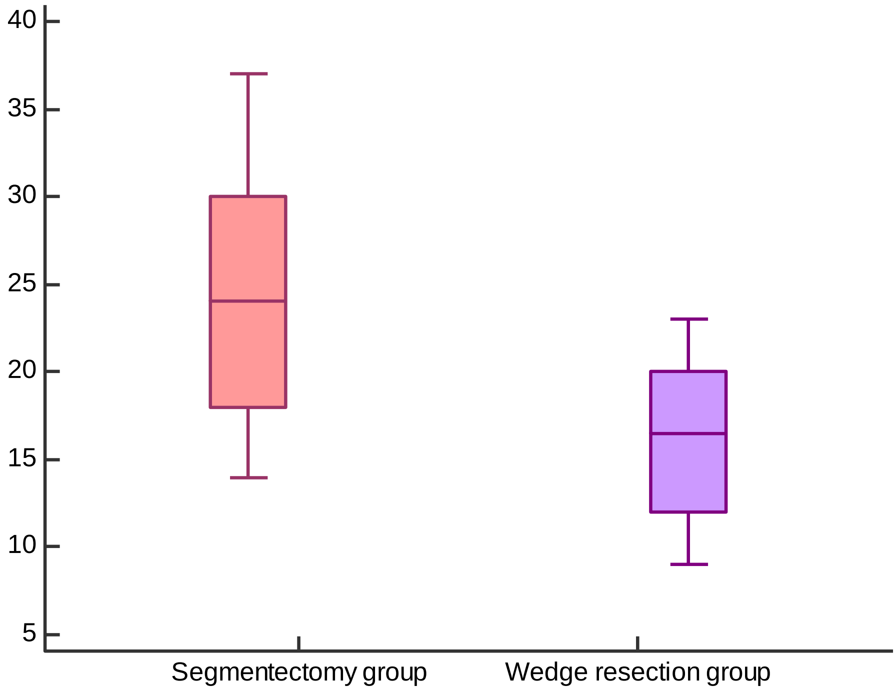

Figure 1: Length of staplers trace on chest CT of the studied groups

Preoperative pulmonary function and postoperative changes of pulmonary function are shown in Table 3. No discrepancy was noticed when FEV_1 loss between two groups were compared (17.4 ± 1.41 vs. 18.2 ± 2.93%). FVC loss after segmentectomy was significantly greater than after wedge resection (17.1 ± 1.58%, vs. 7.9 ± 1.59% $P < 0.001$). Preoperative pulmonary function (FEV_1 and FVC) was statistically different between the two groups of patients, whereas other parameters (pre FEV1 %, pre FVC % and pre FEV1/-FVC) were insignificantly different between both groups. Postoperative pulmonary function (FEV_1, FVC and FEV1/-FVC) was statistically different between the two groups of patients. Incidence of post operative delirium was insignificantly different between the studied groups (2.5% vs. 5 %).

Table 3: Preoperative pulmonary function and postoperative changes of pulmonary function after VATS resections and post operative delirium between the studied groups

	Wedge resection group (n = 40)	Segmentectomy group (n = 40)	P value
Preoperative pulmonary function			
Pre FEV_1 (L)	2.2 ± 0.32	2.7 ± 0.38	**<0.001***
Pre FEV_1 (%)	88.6 ± 4.49	87.8 ± 4.53	0.430
Pre FVC (L)	2.4 ± 0.44	3.3 ± 0.46	**<0.001***
Pre FVC (%)	89.8 ± 2.93	89.5 ± 3.28	0.616
Pre FEV_1/-FVC (%)	88.3 ± 7.9	87.4 ± 10.02	0.654
Postoperative pulmonary function			
Post FEV_1 (L)	1.8 ± 0.29	2.3 ± 0.38	**<0.001***
Post FVC (L)	2.2 ± 0.3	2.6 ± 0.39	**<0.001***
Post FEV_1/-FCV (%)	78.03 ± 0.8	82.8 ± 1.6	**<0.001***
Pulmonary function loss			
FEV_1 loss (%)	17.4 ± 1.41	18.2 ± 2.93	0.112
FVC loss (%)	7.9 ± 1.59	17.1 ± 1.58	**<0.001***
Postoperative delirium	1 (2.5%)	2 (5%)	1.00

Data are presented as mean ± SD or frequency (%), FEV_1: Forced expiratory volume in 1 s; FVC: Forced vital capacity, *: statistically significant as P value <0.05.

Linear regression result showed that the change of preoperative pulmonary function was not able to trigger the change of FVC loss. Figure 2

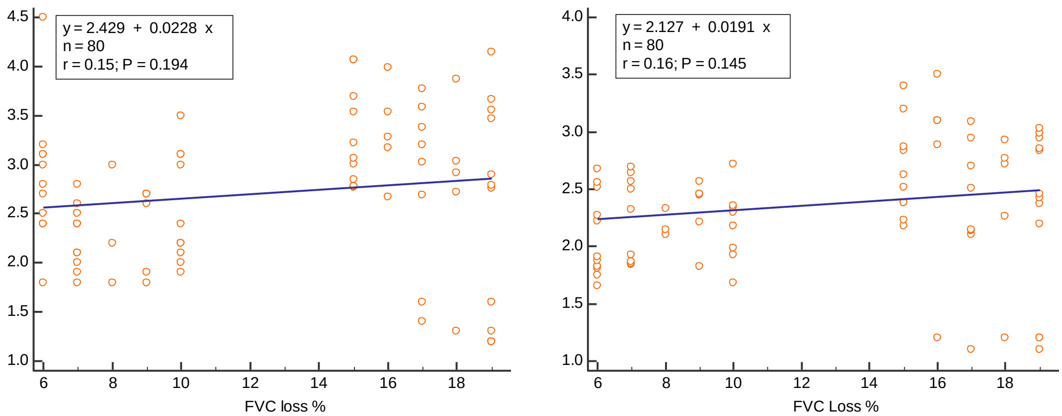

Figure 2: Linear regression result showed that the change of preoperative pulmonary function was not able to trigger the change of FVC loss

Discussion

Sublobar resection as a surgical procedure that can be accepted by thoracic surgeons for the treatment of early staged NSCLC is becoming prevalent. [15] Many literatures have reported that sublobar resection is suitable for small pulmonary nodules with GGO. [16, 17]

VATS is often preferred for patients with subpleural nodule, evidence has accumulated that the early and late outcomes of VATS are comparable or even superior to those of open thoracotomy [18]. With respect to oncological outcomes, VATS showed equivalent or better intermediate to long-term outcomes compared with conventional thoracotomy. Yang et al. reported on the long-term after VATS lobectomy or thoracotomy based on the National Cancer Data Base of United States. [19] About 3,000 patients with stage I non-small cell lung cancer (NSCLC) were matched with propensity score.

Since the introduction of the UVATS approach, numerous reports have shown that UVATS anatomical lung resection can be a feasible and safe alternative compared with traditional VATS anatomical lung resection with regard to short-term oncological outcomes, effective postoperative pain control, shorter duration hospital stay, in-hospital mortality and postoperative complication rates. [20]

However, it is still indeterminate which kind of sublobar resection has more or less effects on lung function after surgery. [21] While segmentectomy requires a high level of thoracoscopic operation and familiarity with anatomy for thoracic surgeons. For various reasons, thoracic surgeons sometimes fall into a dilemma in preoperative evaluation. [22]

In this retrospective study, we examined loss of FVC and FEV1 in patients who underwent UVATS resection of resection type (segmentectomy, or wedge resection). We limited the study sample to include patients who underwent UVATS only in order to reduce the confounding effect of different, multiple, and extended surgical incisions related to pulmonary function. To our knowledge, there are lack of studies that investigate evaluate changes in postoperative pulmonary function changes after undergoing VATS wedge resection and VATS segmentectomy anatomical lung resection.

Our study showed that compared with the segmentectomy group, the wedge resection group had less operation time, less thoracic drainage and shorter hospital length. This came in line with Feng et al. who found that patients undergoing wedge resection had partial advantages over patients with segmental resection in terms of hospitalization cost, operation time and postoperative drainage. [23]

Our findings showed that the pulmonary function at 6 months after operation decreased in both groups. No significant statistical differences were found on postoperative FEV 1 loss after different types of sublobar resection (wedge and segmentectomy resection). segmentectomy could cause more FVC loss more than to wedge resection.

Previous study showed that FEV 1 will begin to recover around 6 months after wedge resection, and FVC then recovered to near the preoperative level after 12 months. [24] Therefore, we hypothesized that if the PFTs was performed 1 year after operation, pulmonary function of patients in wedge resection group and segmental resection group might return to a similar level. So, we chose to measure the postoperative pulmonary function 6 months after operation, this made it possible to observe which surgical procedure has a greater early effect on patients' postoperative lung function. This follow-up scheme has also been adopted by other scholars. [25]

In harmony with our results Feng et al. found that No significant divergences were discovered when comparing FEV1 loss (19.4±5.4% segmentectomy vs. 17.6±2.1% wedge resection, P =0.176), while all patients underwent uniportal VATS wedge resection or segmentectomy. [23] Previous studies have confirmed that the FEV 1 loss in patients undergoing thoracotomy is significantly greater than that in patients undergoing thoracoscopic surgery [26], they considered that the changes of FEV 1 after pneumonectomy might be related to surgical approach, similar views have also been accepted by other researchers. [27]

A 2017 comprehensive systematic review concluded that postoperative pulmonary function stabilized approximately 6-12 months after surgery and that postoperative FEV1 loss was 4%e7% greater after lobectomy than after segmentectomy. [28] However, resection volumes in the included articles widely varied from lobectomy to segmentectomy, even including wedge resections; moreover, most articles included thoracotomy or mixed open and VATS procedures and postoperative PFT differed considerably between studies. In a large multicentre study published in 2006, postoperative FEV1 change did not significantly differ between lobectomy and segmentectomy. [29] However, studies that are more recent have suggested that postoperative lung function is better after segmentectomy. [30-32]

Tane et al. compared residual lung function after VATS lobectomy and segmentectomy using three-dimensional CT volumetry and concluded that although the decrease in lung function in the residual lobe was greater than predicted after segmentectomy, and this functional decrease became greater with increasing extent of resection, whole lung function preservation was better after segmentectomy than after lobectomy. [31]

In the present study, no discrepancy was noticed when FEV_1 loss between two groups were compared. FVC loss after segmentectomy was significantly greater than after wedge resection (17.1 ± 1.58%, vs. 7.9 ± 1.59% P < 0.001). Preoperative pulmonary function (FEV_1 and FVC) was statistically different between the two groups of patients. Postoperative pulmonary function (FEV_1, FVC and FEV1/-FVC) was statistically different between the two groups of patients. Significant difference in FVC loss was detected between wedge resection group and segmentectomy group could be explained by that the application of linear cutting stapler in the intersegmental plane will limit the re-expansion of the remaining lung segments, same view has also been clarified in other literature. [33] Although the cutting stapler was used to complete lung resection in both groups, re-expansion of residual lung might be more difficult in the segmentectomy group than in the wedge resection group. Several patients who underwent segmentectomy had more pronounced and dense stapler traces visible on chest CT when reviewed 3 months after surgery, which might restrict the re-expansion of remaining lung, data analysis also confirmed this notion. [23]

However, previous studies have noticed that due to various reasons (different pulmonary function interval time, impacts caused by surgical incisions and different re-expansion after various extent of resection, etc.), postoperative pulmonary function might be inaccurately predicted by segment counting method. [28, 32, 34] It is difficult to determine precisely whether a patient is fit for VATS segmentectomy. Interestingly, a study has pointed out that not all segmentectomies preserve pulmonary function well, even sometimes lobectomy preserves more lung function relative to segmentectomy [35], this study results also equally corroborated Feng et al. view. [23]

Whether minimally invasive procedures are associated with better preservation of pulmonary function also remains controversial. In an early 1997 prospective study of thoracotomy and thoracoscopic wedge resections, no significant difference was found in postoperative lung function 4 months after surgery. [36] However, two studies reported significantly worse long-term pulmonary function after thoracotomy than after thoracoscopic scoliosis surgery, even without lung resection. [37, 38]

Our study has limitations as retrospective single centre design, small sample size, and selection bias. In addition, we calculated pulmonary function loss using FVC and FEV1, but did not consider DLCO and MVV. Furthermore, only first-time anatomical lung resections were analyzed, so our findings might not be applicable to repeat or multiple lung resection. Also, postoperative pulmonary function loss was not analyzed with respect to clinical presentation, surgical complications, or mortality.

Conclusions

When comparing their lung function at 6th month after surgery, the loss of FEV1 in patients undergoing wedge resection was not prominently different to that of segmentectomy, wedge resection seemed to have more advantages in preserving patients' FVC and MVV. Wedge resection also showed recognized ability in other aspects (saving treatment costs, reducing operation time, etc.). VATS wedge resection for peripheral non-subpleural nodules were not inferior to that of VATS segmentectomy. Whether wedge resection is superior to segmentectomy requires future comparison of the oncologic outcomes of the two surgical modalities in patients.

Declarations

Ethics approval and consent to participate: the study was approved by the institutional ethical committee. All participants included had signed a consent form.

Consent for publication: All authors give their consent for publication; they all have agreed to publish this work.

Availability for data and material: The data is available upon reasonable request from the authors.

Competing interests: The authors declare that they have no competing interests

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Authors' Contributors: All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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