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Research article

V6 vein-preserving superior segmentectomy: A potentially preferable option

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A R T I C L E I N F O

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Segmentectomy
Segmental veins
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A B S T R A C T

Objective: The increasing identification of pulmonary nodules has led to a growing emphasis on segmentectomy. Nevertheless, the surgical process for segmentectomy is complex and optimizing segmentectomy is a critical clinical concern. This study aimed to evaluate the safety and short- and long-term efficacy of V6-preserving superior segmentectomy.
Methods: We performed a retrospective analysis of patients who underwent thoracoscopic superior segmentectomy at our hospital between January 2019 and June 2020. Eligible patients were categorized into an V6 vein-preserving segmentectomy (VVPS) group and a Non V6 vein-preserving segmentectomy (NVVPS) group depending on the preservation of V6. Primary outcome measures encompassed the evaluation of surgical safety (surgical margins, 3-year overall survival, and disease-free survival), whereas secondary measures included postoperative complication rates, operative time, estimated intraoperative blood loss, length of hospital stay, and associated costs.
Results: The analysis included a final cohort of 78 patients. In the NVVPS group ($n = 43$), 95.3 % of patients exceeded the tumor diameter, and no positive surgical margins were observed. The 3-year overall survival (OS) and disease-free survival (DFS) rates for the NVVPS group were 95.3 %, with no significant differences in OS ($p = 0.572$) and DFS ($P = 0.800$) compared with the VVPS group. Additionally, the median total hospitalization cost for the NVVPS group was 41,400 RMB (IQR, 38,800–43,400), which was significantly lower than that of the VVPS group, showing statistical significance ($P < 0.05$). No statistically significant differences were observed in the incidence of postoperative complications and length of stay between the two groups ($P > 0.05$).
Conclusion: V6-preserving superior segmentectomy is a secure and optimized surgical alternative. Its streamlined procedure facilitates easier adoption in primary healthcare facilities, rendering it a superior choice for superior segmentectomy.

1. Introduction

Lobectomy has traditionally been the standard surgical approach for treating early non-small cell lung cancer (NSCLC) [1]. Recent clinical research has indicated a shift in the approach to peripheral suspected NSCLC nodules with a tumor diameter of ≤2 cm. Notably, findings from the JCOG0802 study suggest that segmentectomy is superior to lobectomy in terms of long-term survival and lung

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function [2]. The CALGB140503 clinical trial suggested that for peripheral NSCLC patients (T $\leq$ 2 cm), sublobectomy is non-inferior to lobectomy in terms of disease-free survival, with comparable overall survival [3]. Similarly, another study recommended segmentectomy as a standard surgical approach for peripheral NSCLC with a tumor diameter of $\leq$2 cm [4]. Collectively, these results indicate that the clinical outcomes of sublobectomy and segmentectomy are comparable to those of lobectomy. The international medical community increasingly recognizes segmentectomy as an effective treatment for early-stage NSCLC. Currently, segmentectomy primarily refers to anatomical segmentectomy, involving the resection of the segmental bronchus, artery, and vein. However, to avoid damaging normal tissue structures, especially anatomical variations of veins, three-dimensional reconstruction of lung segments through imaging is essential before performing anatomical segmentectomy [5,6]. Furthermore, postoperative complications such as prolonged operation time, air leakage, and hemoptysis [7] contribute to the complexity of the segmentectomy procedure, imposing higher technical requirements. These challenges have hindered the widespread adoption and application of segmentectomy in primary hospitals.

Recently, some studies have used fluorescence thoracoscopy [8]. In this technique, indocyanine green is injected when the patient's pulmonary segmental artery is severed. This injection rapidly visualized the segmental plane controlled by the severed artery, eliminating the need to cut the patient's segmental bronchus and vein. Consequently, this method significantly reduces operative time. However, it requires the use of an expensive fluorescent thoracoscope, thereby adding to the economic burden of primary hospitals. Alternatively, selective ligation of the pulmonary artery of the lung segment, ventilation with pure oxygen until lung collapse, and confirmation the plane of the lung segment can be performed. This approach minimizes surgical time and prevents clinical symptoms such as postoperative hemoptysis resulting from intersegmental vein damage [9,10]. Nonetheless, the inability to fully open the segmental gate often compromises the safety of the surgical margins. Therefore, this study investigates a surgical strategy to preserve the pulmonary segment veins. However, there is currently a lack of relevant research on the safety and effectiveness of vein preservation during segmentectomy. Compared with other surgical approaches for segmentectomy, superior segmentectomy is relatively straightforward. The V6 vein's relatively isolated nature compared to other major veins simplifies its direct dissection and identification during surgery. This simplification enhances the precision of its localization and preservation. The V6 vein's isolated structure minimizes the risk of damaging other venous structures, reducing the likelihood of surgery-related complications. Preserving the V6 vein may promote postoperative hemodynamic stability and expedite patient recovery. Consequently, this study chose superior segmentectomy to evaluate the safety of V6-preserving superior segmentectomy and its short and long-term outcomes.

2. Methods and study design

This study adopted a single-center, retrospective, case-control design, incorporating clinical data from all patients who consecutively underwent thoracoscopic superior segmentectomy at our center between January 2019 and June 2020. The study patients were primarily operated on by two highly experienced surgeons, each with over 100 cases of pulmonary segmentectomy experience. Adhering to the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines and aligning with the Helsinki Declaration, the research protocol received approval from the Ethics Committee of our Hospital (L2023-04-074). Owing to the retrospective nature of the study, informed consent from patients encompassed both written and verbal forms. This study aligns with the STROCSS criteria [11].

Inclusion Criteria: Males or females aged 18 years or older who underwent thoracoscopic superior segmentectomy (right lower lung or left lower lung), with clinical stage IA1 and IA2 lung cancer as per the 8th edition of the UICC diagnosis, Consolidation tumor ratio $<$1, performance status of 0 or 1, American Society of Anesthesiologists (ASA) score $<$4, and provision of signed informed consent.

Exclusion Criteria: Preoperative tumor diameter $>$2 cm, benign lung disease requiring superior segmentectomy, undergoing more than one superior segmentectomy, or intraoperative conversion to open chest.

Preoperative Routine Examinations: chest computer tomography (CT), head MRI, echocardiography, pulmonary function tests, electrocardiography, abdominal CT, blood gas analysis, and other relevant examinations.

3. Data collection

Patient information collected: age, sex, smoking status, lung function (FEV1/FVC), ASA classification, tumor diameter, pathological type, surgical margins, operation time, intraoperative estimated blood loss, postoperative drainage, length of stay, hospitalization costs, transfusion events, 3-year overall survival (OS), disease-free survival (DFS), and postoperative complications (lung infection, air leakage, and postoperative hemoptysis). Definitions: Continuous air leak exceeding 48 h was considered for air leak assessment [12], and postoperative hemoptysis was defined as coughing up fresh red blood persisting for 3 days postoperatively [13]. The surgical margin was defined as the closest distance between the surgically removed tumor tissue and excised lung tissue [14].

4. Treatment plan

VVPS requires ligation of superior segment arteries, bronchi, and veins. After ventilation with pure oxygen and a 15-min waiting period, the superior segment tissue was excised using a linear cutting stapler upon identification of the lung segment plane. NVVPS involves ligating the superior segment artery and bronchus while preserving the superior segment vein (V6). Similarly, after ventilation with pure oxygen and a 15-min waiting period, the superior segment tissue was excised using a linear cutting stapler to identify the superior segment plane. Systematic lymph node sampling was performed in all patients (lymph node stations 7 to 12). All patients were provided with consistent perioperative care, encompassing nursing protocols and anesthesia strategies.

5. Study endpoints

The primary outcomes focused on assessing patient surgical safety, covering surgical margins, 3-year overall survival (OS), and disease-free survival (DFS). Secondary outcomes included the incidence of postoperative complications, operation time, intraoperative estimated blood loss, length of stay, and hospitalization costs.

6. Statistical analysis

Data were analyzed using SPSS software (version 23.0, SPSS Inc., IL, USA). Categorical variables are presented as percentages and compared using the chi-square test or Fisher's exact test. Normally distributed continuous variables are expressed as mean ± standard deviation and compared using t-tests. For non-normally distributed continuous variables, the Mann-Whitney *U* test was employed, and the results were presented as median (IQR). Statistical significance was set at $P < 0.05$.

7. Results

Between January 2019 and June 2020, 85 patients underwent consecutively thoracoscopic superior segmentectomy. Two patients were excluded due to not meeting the inclusion criteria (one with ASA = 4 and one refusing written informed consent), while five others met the exclusion criteria. Ultimately, 78 patients met the inclusion criteria for the study. Among them, 35 patients underwent VVPS and 43 patients underwent NVVPS, as detailed in Fig. 1.

The average age of the patients in the NVVPS group was 58.33 years (SD, 8.0), with 20 males (46.5 %). A total of 41 patients (95.3 %) were classified as ASA grade 1 or ASA grade 2, and 34 patients (79.1 %) had FEV1/FVC ≥80 %. Only three cases (7.0 %) were diagnosed with invasive adenocarcinoma, and among these, 20 (46.5 %) had tumors on the left side. No lymph node metastasis was found in both groups. No significant differences in preoperative clinical characteristics were observed between the two groups ($P > 0.05$) (Table 1).

Surgical Safety Assessment: In the VVPS group, 29 patients (82.9 %) had surgical margins ≥1 cm, while 35 patients (81.4 %) in the NVVPS group also had surgical margins ≥1 cm. No positive surgical margins were observed in either group, and there was no significant difference in the surgical margins between the two groups ($P = 0.867$). Additionally, in the NVVPS group, 41 patients (95.3 %) had surgical margins larger than the tumor diameter, compared to 34 patients (97.1 %) in the VVPS group, with no significant difference between the two groups ($P = 1.00$). The 3-year OS in the VVPS group reached 97.1 %, with one patient experiencing death due to a traffic accident in the 12th postoperative month. The 3-year DFS was 94.3 %, with one patient developing a solitary metastatic nodule in a different lung lobe at the 30th postoperative month and subsequently undergoing reoperation. In the NVVPS group, the 3-year OS was 95.3 %, with one patient dying from acute myocardial infarction at the 26th postoperative month and another succumbing to coronavirus disease 2019 infection at the 10th postoperative month. The 3-year DFS rate was 95.3 % in the NVVPS group, with no cases of tumor recurrence. No deaths caused by primary tumor events occurred in either group, and there were no significant differences in the 3-year OS and DFS between the two groups ($P > 0.05$). Refer to Table 2, Fig. 2, and Fig. 3 for further details.

As expected, the median surgical time in the NVVPS group was 120 min (interquartile range (IQR), 105–135), which was

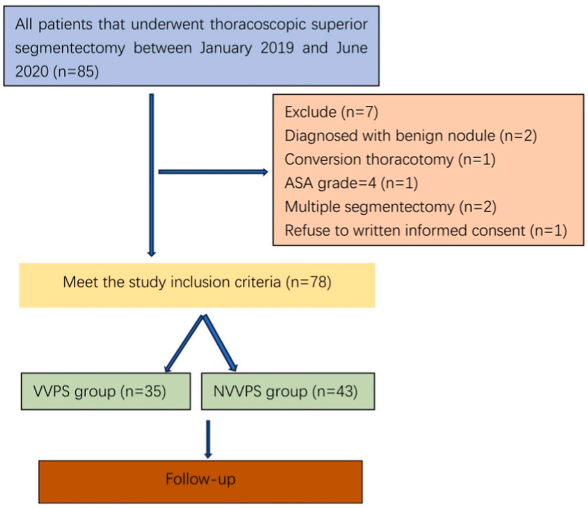

Fig. 1. Details of the study enrollment. ASA = American anesthesia score; VVPS=V6 vein-preserving segmentectomy, NVVPS=Non V6 vein-preserving segmentectomy.

Table 1
Preoperative patient characteristics.

	VVPS group (n = 35)	NVVPS group (n = 43)	P value
Age, years, mean (SD)	57.29 (10.6)	58.33 (8.0)	0.624
Male Sex, n (%)	13 (37.1)	20 (46.5)	0.405
ASA Class			0.652
1/2	32 (91.4)	41 (95.3)	
3	3 (8.6)	2 (4.7)	
Smoking status, n (%)			0.282
Never/former	23 (65.7)	33 (76.7)	
Current	12 (34.3)	10 (23.3)	
FEV1/FVC, n (%)			0.838
≥80 %	27 (77.1)	34 (79.1)	
<80 %	8 (22.9)	9 (20.9)	
Tumor diameter, n (%)			0.308
≤1 cm	27 (77.1)	37 (86.0)	
1–2 cm	8 (22.9)	6 (14.0)	
Tumor histological, n (%)			0.456
AIS	11 (31.4)	18 (41.9)	
MIA	19 (54.3)	22 (51.2)	
IA	5 (14.3)	3 (7.0)	
CTR, n (%)			0.233
<0.5	30 (85.7)	41 (95.3)	
≥0.5	5 (14.3)	2 (4.7)	
Location, n (%)			0.15
left side	22 (62.9)	20 (46.5)	
Right side	13 (37.1)	23 (53.5)	

SD = standard deviation; FEV1= Forced Expiratory Volume in the first second; FVC= Forced Vital Capacity; AIS = adenocarcinoma in situ; MIA = Microinvasive adenocarcinoma; IA = invasive adenocarcinoma; CTR= Consolidation tumor ratio; VVPS=V6 vein-preserving segmentectomy, NVVPS=Non V6 vein-preserving segmentectomy.

significantly shorter than that in the VVPS group 130 min (IQR, 122–148), and the difference was statistically significant ($P < 0.002$). The median estimated intraoperative blood loss in the NVVPS group was 60 ml (IQR, 50–80), which was significantly lower than the VVPS group's intraoperative estimated blood loss of 80 ml (IQR, 70–100.0), and the difference was statistically significant ($P < 0.001$). The median hospitalization cost in the NVVPS group was 41,400 RMB (IQR, 38,800–43400), lower than the VVPS group's median hospitalization cost of 45,400 RMB (IQR, 41,500–47800), and the difference was statistically significant ($P = 0.003$). Although the postoperative rates of air leakage (11.6 %) and postoperative hemoptysis were significantly lower in the NVVPS group than in the VVPS group, these differences were not statistically significant ($P > 0.05$). One intraoperative transfusion event occurred in the NVVPS group without severe complications. There were no significant differences between the two groups in terms of transfusion events, length of stay, or postoperative drainage ($P > 0.05$) (Table 2).

Table 2
Postoperative clinical outcomes.

	VVPS group (n = 35)	NVVPS group (n = 43)	P value
Surgical margin, n (%)			0.867
<1 cm	6 (17.1)	8 (18.6)	
≥1 cm	29 (82.9)	35 (81.4)	
Surgical margin, n (%)			1.00
<tumor diameter	1 (2.9)	2 (4.7)	
≥tumor diameter	34 (97.1)	41 (95.3)	
Blood transfusion event, yes, n (%)	0	1	1.00
Hospitalization expenses, RMB, median (IQR)	45,400 (41,500–47800)	41,400 (38,800–43400)	0.003
Operative time, min, median (IQR)	130 (122–148)	120 (105–135)	0.002
Length of stay, days, median (IQR)	4.0 (3.0–5.0)	4.0 (3.0–5.0)	0.615
Estimated Blood Loss, ml, median (IQR)	80.0 (70–100.0)	60.0 (50.0–80.0)	<0.001
Postoperative drainage, ml, median (IQR)	150.0 (110–150)	150.0 (120–210)	0.622
3-year OS, n (%)	34 (97.1)	41 (95.3)	0.572
3-year DFS, n (%)	33 (94.3)	41 (95.3)	0.800
Postoperative complications, n (%)			
Air leakage	7 (20.0)	5 (11.6)	0.308
Lung infection	1 (2.9)	2 (4.7)	1.00
Hemoptysis	3 (8.6)	0 (0)	0.086

RMB=Renminbi; IQR = interquartile range; VVPS=V6 vein-preserving segmentectomy, NVVPS=Non V6 vein-preserving segmentectomy; OS = overall survival; DFS = disease-free survival.

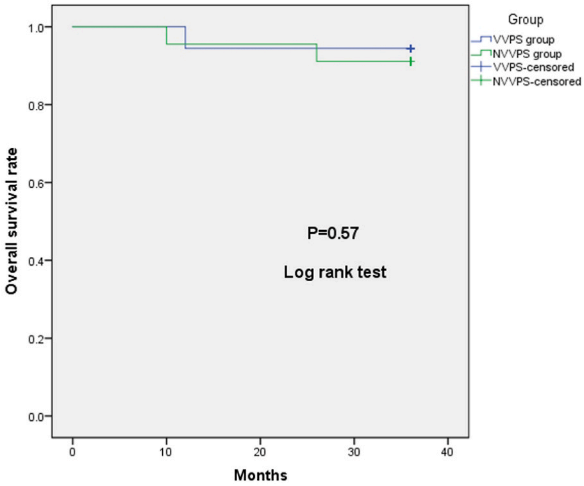

Fig. 2. Comparative analysis of 3-year overall survival rate between two groups. VVPS=V6 vein-preserving segmentectomy, NVVPS=Non V6 vein-preserving segmentectomy.

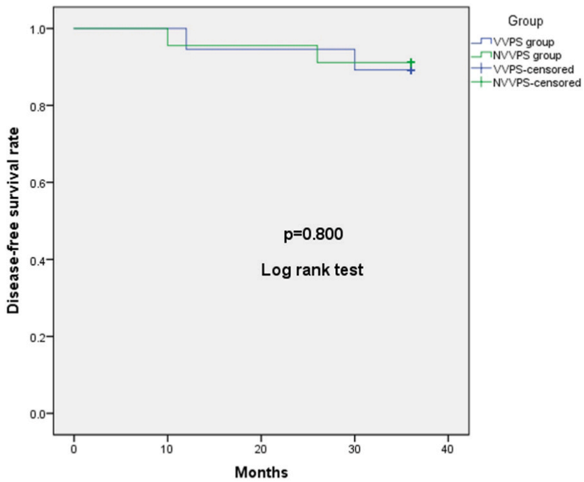

Fig. 3. Comparison of the 3-year disease-free survival rate between two groups. VVPS=V6 vein-preserving segmentectomy, NVVPS=Non V6 vein-preserving segmentectomy.

8. Discussion

Several studies suggest that compared to lobectomy, segmentectomy better preserves lung function, especially in patients with compromised preoperative lung function who are not suitable for lobectomy [15,16]. In the future, sublobectomy or segmentectomy is expected to be the predominant approach for peripheral NSCLC [17]. Segmentectomy, a more intricate form of sublobectomy, presents a challenge in simplifying complex surgical procedures, as envisioned by clinicians. However, the complexity of lung segment surgery hinders its adoption in primary hospitals. This study began with an exploration of the relatively straightforward superior segmentectomy, with the aim of evaluating the safety and efficacy of a simplified approach to superior segmentectomy.

Initiating with anatomical analysis, it is common in anterior or posterior segmentectomy to ligate veins to expose the arteries and bronchi behind. However, in superior segmentectomy, the anatomical position of V6 has no impact on ligation of the superior segmental artery and bronchus, starting from the oblique fissure. This anatomical characteristic served as the foundation for this study.

Among the 78 eligible patients who underwent thoracoscopic superior segmentectomy, nearly 45 (57.7 %) chose V6-preserving NVVPS. Surgeries in the NVVPS group were considered safe, with no cases of positive margins in either group; 81.4 % of patients in both groups had margins greater than 1 cm. Additionally, as suggested by some studies [18], maintaining surgical margins exceeding the tumor diameter is crucial for preventing tumor recurrence. In this study, 41 patients (95.3 %) in the NVVPS group exhibited margins larger than the tumor diameter. Regarding long-term efficacy, the 3-year OS and DFS rates were comparable between the two groups, with no significant differences. No instances of primary tumor-causing patient death occurred, and the NVVPS group experienced no postoperative tumor recurrence. This outcome may be attributed to the biological characteristics of the selected patients. In the NVVPS group, only three patients had postoperative pathology indicating invasive adenocarcinoma, while the rest showed adenocarcinoma in situ or minimally invasive adenocarcinomas, consistent with previous clinical research results [2] These data collectively confirm the safety of the NVVPS surgical approach.

The NVVPS group showed statistically significant reductions in total hospitalization expenses compared to the VVPS group. This could be due to preserving the V6 vein, simplifying the surgical anatomy, and potentially reducing the use of vascular staple cartridges. Kandathil et al. suggest [19] that V6c belongs to the intersegmental veins, and complete dissection of V6 may damage these veins. Mimae et al. [20] have proposed that injuring intersegmental veins may elevate the risk of postoperative hemoptysis complications. Although there was no significant difference in postoperative hemoptysis complications between the two groups, the VVPS group experienced early mild hemoptysis symptoms in three patients (resolved within one month postoperatively). Moreover, preserving the V6 vein eliminates the need to consider damage to intersegmental veins. This allows the avoidance of preoperative three-dimensional reconstruction of lung segments, leading to a significant reduction in surgical complexity and facilitating implementation in primary hospitals. Additionally, preserving the V6 vein may offer more benefits for basal segment lung function exchange, thereby reducing lung function loss. Unfortunately, this study lacked postoperative lung function follow-up data, which is a limitation of this retrospective research. Prospective clinical studies are needed to address this issue. Nasir et al. suggest [21] that the cost of segmentectomy is higher than that of lobectomy. However, in this study, preserving V6 also reduced the total hospital costs for patients, possibly because of a decrease in the use of staplers.

This study has limitations due to its small sample size and inability to control all potential confounding factors. In addition, being a single-center retrospective study introduced a potential selection bias. Multicenter, prospective and large sample clinical research may reduce selective bias. Favorable factors observed in the NVVPS group, such as surgical time, hospital costs, and intraoperative blood loss, may vary across surgeons and geographical locations, limiting the generalizability of the study results to all centers. Meanwhile, the follow-up time of this study is relatively limited, only 3 years. A 5-year follow-up time might provide a more accurate evaluation of the true long-term survival rate. We will continue to follow up with the data of these patients in the future. However, the simplified approach to superior segmentectomy in this study may enhance the promotion of the V6-preserving superior segmental surgical model, particularly in primary hospitals. Furthermore, a limitation of this study is the absence of clinical data, such as postoperative lung function, which requires further investigation.

9. Conclusion

This study provides preliminary data indicating the safety of V6-preserving NVVPS for NSCLC patients with tumors in the superior segment and a diameter less than 2 cm. This may be an alternative to segmental resection, making it more accessible, particularly in primary hospitals.

Ethics statement

This study was performed in accordance with the Helsinki Declaration and approved by the Ethics Committee of Wenzhou Central Hospital (IRB number: L2023-04-074).

Data availability statement

Data will be made available on request from the corresponding author upon reasonable request.

Consent for publication

Not applicable.

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CRediT authorship contribution statement

Yuan-Liang Zheng: Writing – original draft, Funding acquisition, Data curation, Conceptualization. **Dan-Ni Wu:** Writing – original draft, Supervision, Formal analysis, Data curation. **Ri-Sheng Huang:** Writing – review & editing, Resources, Methodology, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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