Cao et al. BMC Surgery (2024) 24:409
https://doi.org/10.1186/s12893-024-02719-2

BMC Surgery

RESEARCH

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Safety and efficacy of anatomical tunneling technique for precise lung segment resection in complex anatomical settings

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Abstract

Background Thoracoscopic segmentectomy is the main surgical method for the treatment of earlylung cancer. With the promotion of technology and increasingly accurate criteria for lung subsegments, lung nodules with complex positions involving intersegmental and multisegments have become technical bottlenecks. This study aimed to verify whether seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments could solve this bottleneck problem.

Methods The clinical data of patients with lung nodules ≤ 2 cm located in the complex position in the Department of Thoracic Surgery of Jiangsu Provincial People's Hospital from January 2019 to August 2023 were collected. Date analyzed the characteristics of patients who underwent seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments (segment group) at complex setting and compared the surgical outcomes and complications between these lobectomy patients (lobectomy group) at similar locations.

Results A total of 22 patients were included segment group and 47 patients were included lobectomy group. Except for the depth ratio or tumor size or consolidation tumor ratio (CTR), there were no significant differences in the other baseline data between the two groups. All patients in segment group received a satisfactory surgical margin. Compared to the lobectomy group, surgical outcomes were better in segment group ($p < 0.05$ for postoperative hospital stay and the counts of resected subsegments).

Conclusion Seeking anatomical conditions for creating a fissure by tunneling techniques is a promising technique for performing precise resection of lung segments with a safe resection margin for patients with lung nodules at complex positions involving multiple segments. It can be used as a precise resection of lung segments technique.

Keywords Lobar split cone-shaped subsegmentectomy, Lobectomy, Intersegmental lung nodules, Multisegment lung nodules, Video-assisted thoracoscopic surgery

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Introduction

Designed by the American Lung Cancer Study Group (LCSG) in 1982, the world's first multicenter randomized controlled prospective trial, LCSG821, on sublobectomy for the treatment of early lung cancer established lobectomy as the standard surgical treatment for early lung cancer [1]. With the spread of computerized tomography (CT) imaging of the lungs and advances in staging methods, smaller and earlier tumors are being detected, which has led to renewed interest in sublobectomy in patients with early lung cancer [2, 3]. After more than 40 years of comparative studies on the effects of different surgical methods for early lung cancer, it was found that for peripheral lung nodules ≤ 2 cm and pure ground glass opacity, it is feasible to perform thoracoscopic lung segmentectomy, which can achieve the same effect as radical lobectomy [4, 5]. The latest and influential research results of CALGB140503, JCOG0802 and JCOG0804 suggest that lung sublobectomy can replace lobectomy for the treatment of pure solid peripheral early lung cancer with a diameter less than 2 cm [6–10] and that sublobectomy can be used to lengthen the tumor height to a new height.

However, precise lung segment resection [5] in complex anatomical settings is very challenging. These lung nodules in complex positions involving intersegmental and multisegmental regions, such as lung nodules are located in the middle third lung field LS3, LS2, and LS1; or RS1 and S3a; or RS1b, S2b and S3a; or RS1b and S3a; or RS8a and S9; or RS6 and S9. If the lung nodule at these locations were operated on precise lung segment resection, it was difficult to dissect the correct lung hilar structure. Also, the anatomic approach to performing precise lung segment resection was difficult. In addition, it was difficult to identify the boundary of the adjacent lung segment anatomically, and it was difficult to receive a satisfactory surgical margin in precise lung segment resection.

Therefore, this study aimed to verify whether seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments could solve this bottleneck problem.

Methods

Study design and participants

We retrospectively screened patients with lung nodules in complex positions involving intersegmental and multisegmental regions (Fig. 1) who underwent creating a fissure by tunneling techniques with precise resection of lung segments and lobectomy at our center between January 2019 and August 2023. The patients were named the segment group and lobectomy group, respectively.

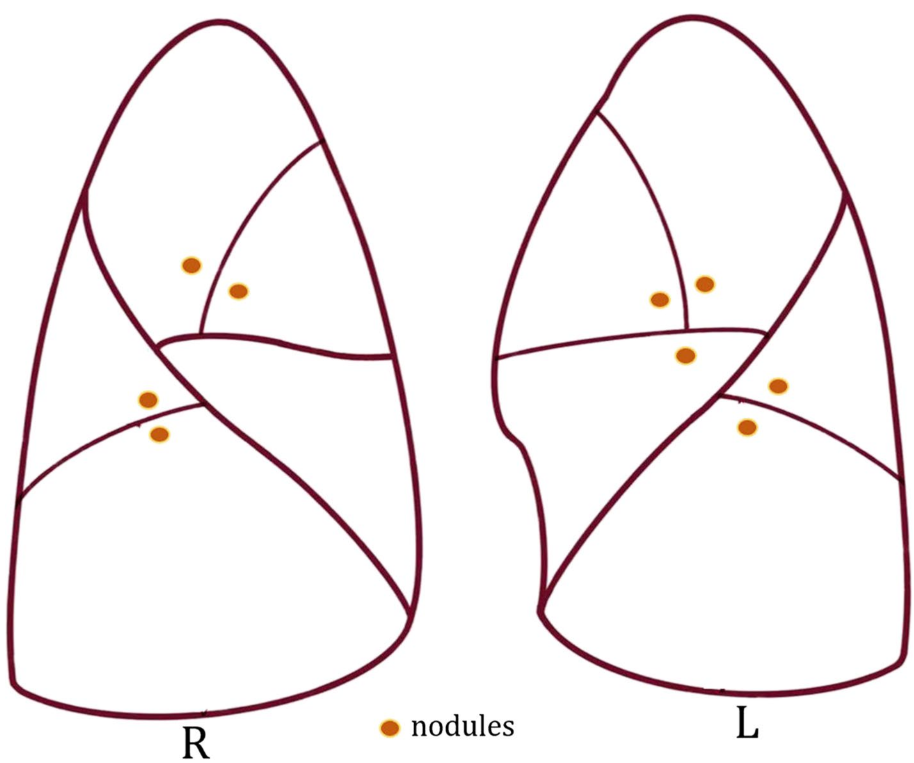

Fig. 1 Lung nodule location map

Inclusion criteria: (1) the operation was performed by the surgeons with more than five years related experience in performing segmentectomy independently; (2) the number of segmentectomy operations performed by the surgeon in the past five years was more than 1000; (3) the lung segmentectomy operation was performed by precise resection of lung segments as our defined; (4) the collected data should have intact surgical videos.

Exclusion criteria: (1) Poor lung function, unable to tolerate lobectomy; (2) Pure solid lung nodules; (3) Pleural retraction and/or pleural depression; (4) Handling unplanned events for more than 30 min during operation; (5) More than two lung nodules requiring surgical intervention; (6) Incomplete clinical data.

The included patients were divided into two groups according to the surgical way, segment group and lobectomy group. The specific case screening process is shown in Fig. 2.

Surgical procedures

Before the operation, three-dimensional (3D) reconstruction was performed for patients seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments at complex setting. 3D reconstruction accurately simulated lung segmentation and lesions and was planned according to the tracheal branches, arteries, and veins. The positions and adjacent tissue (blood vessels, bronchus) lung nodules were labeled to guide the lung segmentation, and resection margin spheres were generated 2 cm from the lesion edge. The reconstruction results were reviewed by comparison with the preoperative CT images, and the resection schemes were planned jointly by experienced surgeons with three associate director titles or above.

The positions in the segment group included LS1 + 2c + S3a, LS3, LS3a + b, LS1 + 2c + S3, RS1 + S3a, RS1b + S2b + S3a, RS1b + S3a, S9, RS8a + S9, and RS6 + S9. The method of establishing the tunneling technique for LS1 + 2c + S3a, LS3, LS3a + b, and LS1 + 2c + S3 involved dissecting A4 + 5 at the oblique fissure and opening the posterior mediastinal pleura to dissect A1 + 2c (Fig. 3). In this way, the spacings between A4 + 5 and A1 + 2c are used to establish splitting hatchway 1. Then, opening the anterior mediastinal pleura for dissecting V3b exposes the space between B4 + 5 and B3, which splits Hatchway 2. Lobar splitting between hatchway 1 and hatchway 2 was performed using a stapler. For RS1S + 3a, RS1b + S2b + S3a, and RS1b + S3a (Fig. 4), dissection of the target vein, target artery and target bronchus were performed first. Then, the spacings between B1b and B3b were exposed, which was splitting hatchway 1. The spacings between B3a and B3b were determined by splitting hatchway 2. Additionally, for S9 and S8a + S9 (left lung for Fig. 5, right lung for Fig. 6), dissection of the target vein, target artery and target bronchus were performed. Then, the spacings between B8a and B8b were exposed, which was tunneling hatchway 1. The spacings between B9 and B8 were split into hatchway 2. Tunneling technique between Hatchway 1 and Hatchway 2 was also performed using a stapler.

The structures of hatchway 1 and hatchway 2 to be severed in both directions were determined during the

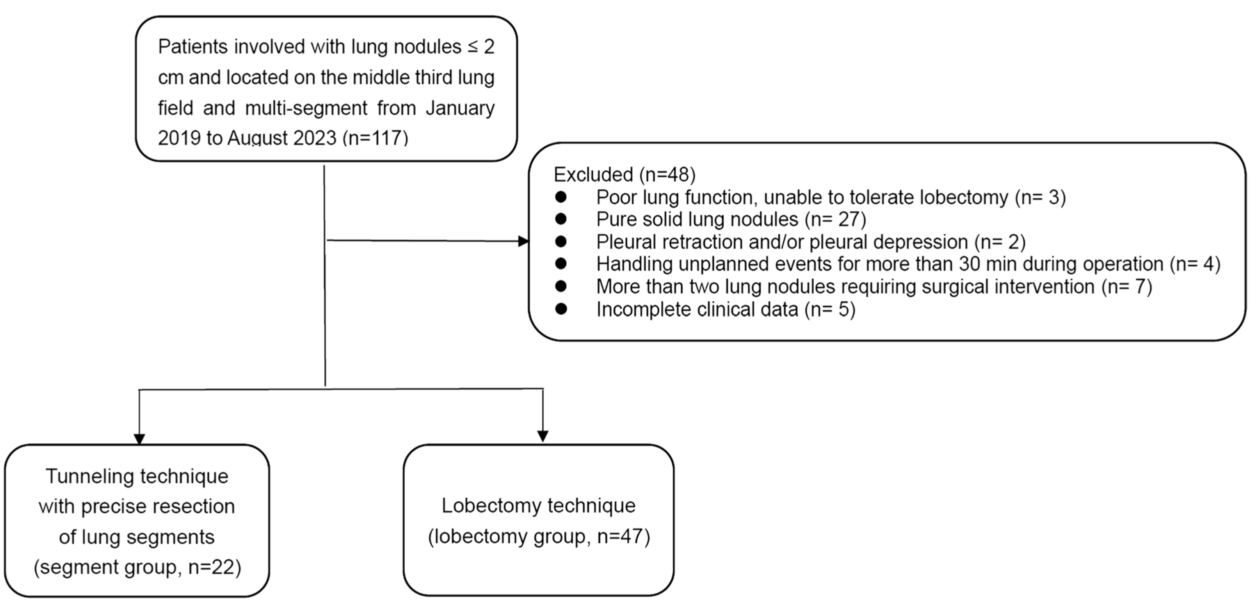

Fig. 2 Flowchart of patients. A total of 117 patients met the inclusion and exclusion criteria, and 69 patients were included in this study

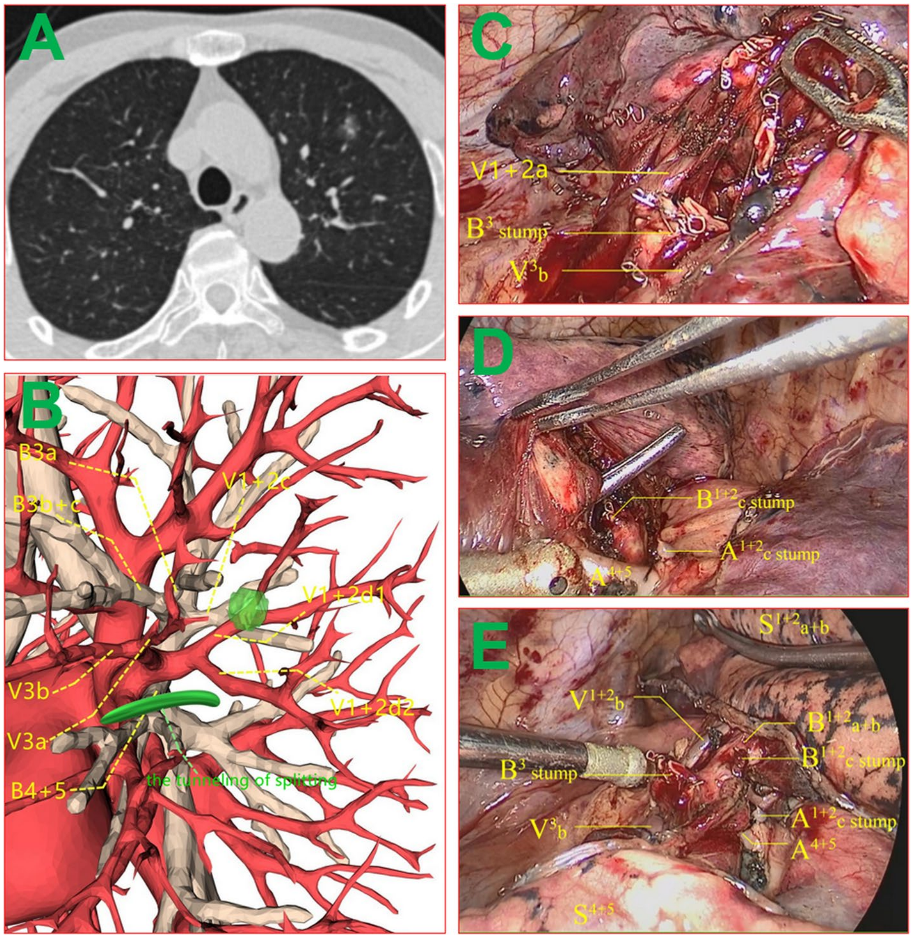

Fig. 3 Radiological images and surgical procedure images of a left superior lobe lung nodule (**A**) Lung window from computed tomography; (**B**) Three-dimensional images of bronchography and vasculature computed tomography; (**C**) Tunneling hatchway 1; (**D**) Tunneling hatchway 2; (**E**) Surgical field after creating a fissure by tunneling techniques with precise resection of lung segments

preoperative simulation according to 3D reconstruction. During establishing the tunneling, it is necessary to check whether there are still vessels or bronchi. If these abnormalities are found, there may be errors in the surgical anatomy. Before tunneling technique, the inflation–deflation method for distinguishing the intersegmental plane is also necessary. The combination of sharp-blunt dissection, "work-plane extension", and the "gate" opening technique contributes to the accuracy of tunneling technique [11–13]. The lung lobe was subsequently divided into normal lung tissue and contained the lesion target lung tissue after tunneling technique. The target arteries and bronchus of the target segment and the adjacent segment were exposed, and the internal veins of the target segmentectomy were removed to preserve the intersegmental veins so that the resection of multiple subsegments could be combined into one resection unit [5, 13].

For the tissue with lesions surgically resected, we measured the surgical margins in all patients. The surgical margins were calculated based on the shortest distance between the tumor boundary and the line connecting the clip on the pleura with the staples on the bronchial stump [14]. Our minimum requirement is that the surgical margin distance be $\geq$ the maximum diameter of the tumor or 2 cm; otherwise, lung lobectomy will be performed. The rest of the surgical procedures is as usual lung segmentectomy.

Data collection and analysis

The eligible medical records were compared and analyzed in terms of age, sex, nodule size (cm), nodule location, nodule type, nodule depth ratio, consolidation tumor ratio (CTR), surgical margin distance, operation time (min), intraoperative blood loss (ml), postoperative hospital stay (days), and postoperative lung air leakage.

According to the depth ratio method, the bronchial cross-section center of each unit was set as the starting point, and the center of the lesion extended to the

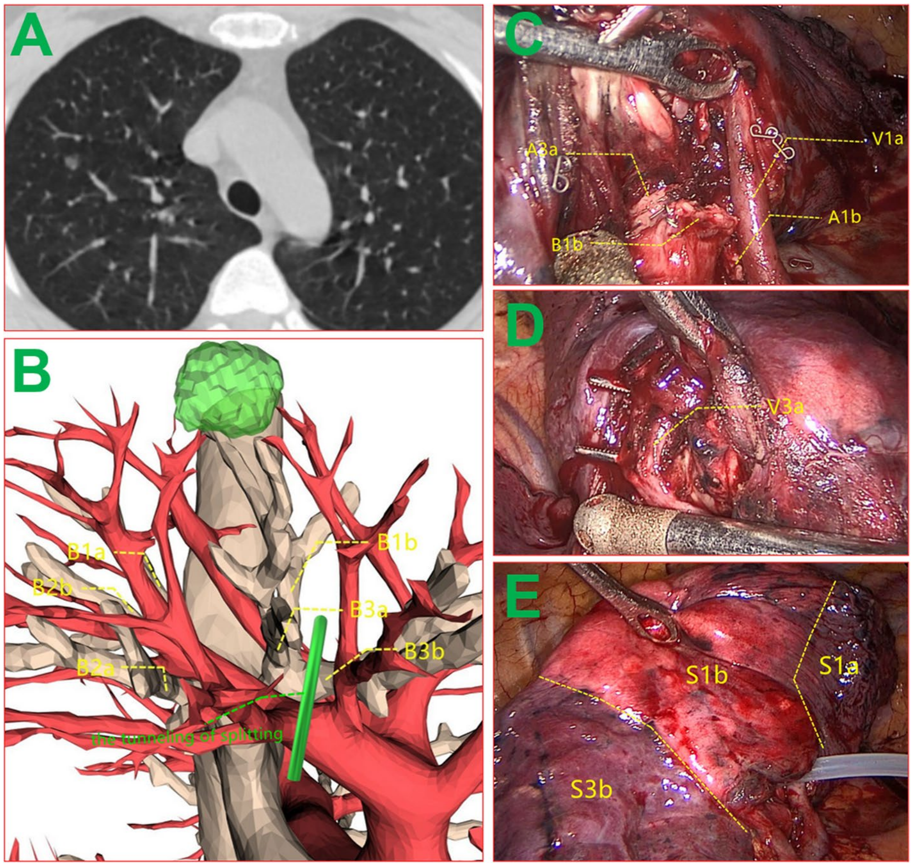

Fig. 4 Radiological images and surgical procedure images of right superior lobe lung nodules (**A**) Lung window from computed tomography; (**B**) Three-dimensional image of the bronchography and vasculature from computed tomography; (**C**) Tunneling hatchway 1; (**D**) Tunneling hatchway 2; (**E**) Lung tissue required for creating a fissure by tunneling techniques with precise resection of lung segments

endpoint on the pleura. Trisection of the lung field was conducted into the outer third lung field (0–33.3%), middle third lung field (33.4–66.6%), and inner third lung field (66.7–100%) [15].

The data are presented as the mean ± standard deviation for continuous variables and as absolute numbers and percentages for categorical variables. Categorical variables were assessed using χ2 tests or Fisher's exact tests as appropriate, while *t* tests were conducted for continuous variables with independent samples. The nonnormally distributed data were compared between groups by *the* U test. A p value ≤ 0.05 indicated statistical significance. All the statistical analyses were performed using SPSS version 26.0 software.

Results

Patient characteristics

Our study included 69 patients (Table 1), of whom the mean age was 56.19 ± 10.71 years, 46 (66.7%) patients were female, and 22 (31.9%) patients were smokers. The mean tumor size was 1.32 ± 0.40 cm. Twenty-two patients were included in the segment group, and 47 were included in the lobectomy group. In total, four lobes and three pathological types of lung nodules from patients who underwent segmentectomy were evaluated. Except for the depth ratio (0.43 ± 0.13 vs 0.56 ± 0.13, $p < 0.001$) or tumor size (0.98 ± 0.31 vs 1.49 ± 0.34, $p < 0.001$) or CTR (0.27 ± 0.19 vs 0.47 ± 0.33, $p = 0.003$), there were no significant differences in the other baseline data between the two groups.

Surgical outcomes between the segment group and lobectomy group

Compared with those of the lobectomy group, the main surgical evaluation indices of the segment group, including operation time (146.91 ± 47.04 min vs 124.36 ± 31.83 min, $p = 0.0501$), intraoperative bleeding (44.55 ± 26.68 mL vs 48.30 ± 33.90 mL, $p = 0.649$) and the occurrence of air leakage (9.09% vs 4.26%, $p = 0.956$), were not disadvantageous. The postoperative hospital stay decreased in the segment group (3.36 ± 0.66 days vs 4.74 ± 2.19 days, $p < 0.001$). Seeking anatomical conditions

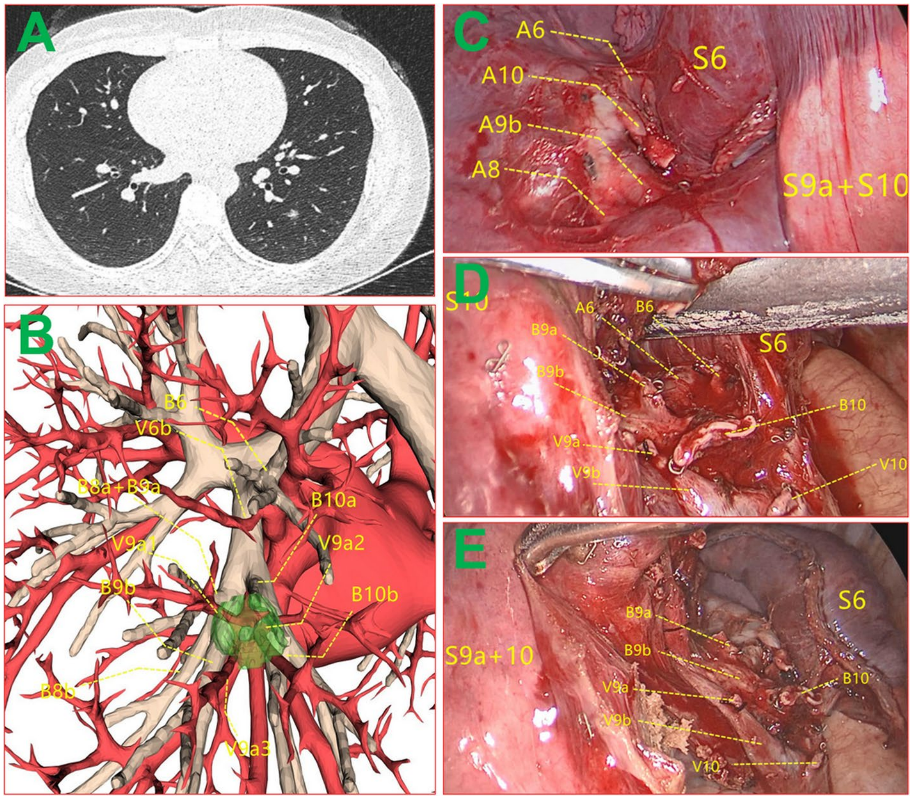

Fig. 5 Radiological images and surgical procedure images of a left lower lobe lung nodule. (**A**) Lung window obtained via computed tomography; (**B**) Three-dimensional images of bronchography and vasculature obtained via computed tomography; (**C**) Tunneling Hatchway 1; (**D**) Tunneling Hatchway 2; (**E**) Surgical field after creating a fissure by tunneling techniques with precise resection of lung segments

for creating a fissure by tunneling techniques with precise resection of lung segments for patients with intersegmental and multisegment lung nodules received a satisfactory surgical margin. The detailed data are given in Table 1. The mean counts of resected subsegments in the segment group was less than that in the lobectomy group (2.45 vs 8.64, $p < 0.001$). The mean counts of resected subsegments with the left upper lung in the segment group was less than that in the lobectomy group (2.75 vs 10), and the mean counts of resected subsegments with the right upper lung in the splitting group was less than that in the lobectomy group (2.33 vs 6). Similarly, the mean counts of resected subsegments with the lower lung in the segment group was less than that in the lobectomy group (2.38 vs 9.67).

The specific details of patients with seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments at complex setting

The operation was successfully completed in all patients. The area of resection included LS1 + 2c + S3a, LS3, LS3a + b, LS1 + 2c + S3, RS1 + S3a, RS1b + S2b + S3a, RS1b + S3a, S9, RS8a + S9, and RS6 + S9. The specific details are shown in Table 2. The patients were all discharged smoothly, and no deaths or pulmonary complications, including pulmonary infection, lung torsion, or bronchopleural fistulas, were observed. Three months after surgical treatment, there was no evidence of pleural effusion, secondary admission, or secondary surgery. During the three-month follow-up period, postoperative lung CT scan revealed well-inflated preserved lung tissues without obvious atelectasis.

Discussion

With the popularity of thin-slice CT scans and the extensive application of artificial intelligence and three-dimensional reconstruction techniques, an increasing number of small lung nodules have been detected [16, 17]. The main treatment for small lung nodules is surgery, which includes lobectomy, segmentectomy and wedge resection [18, 19]. Recently, segmentectomy has been regarded as a common type of surgery [20, 21]. In this study, we demonstrated the seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments at complex setting.

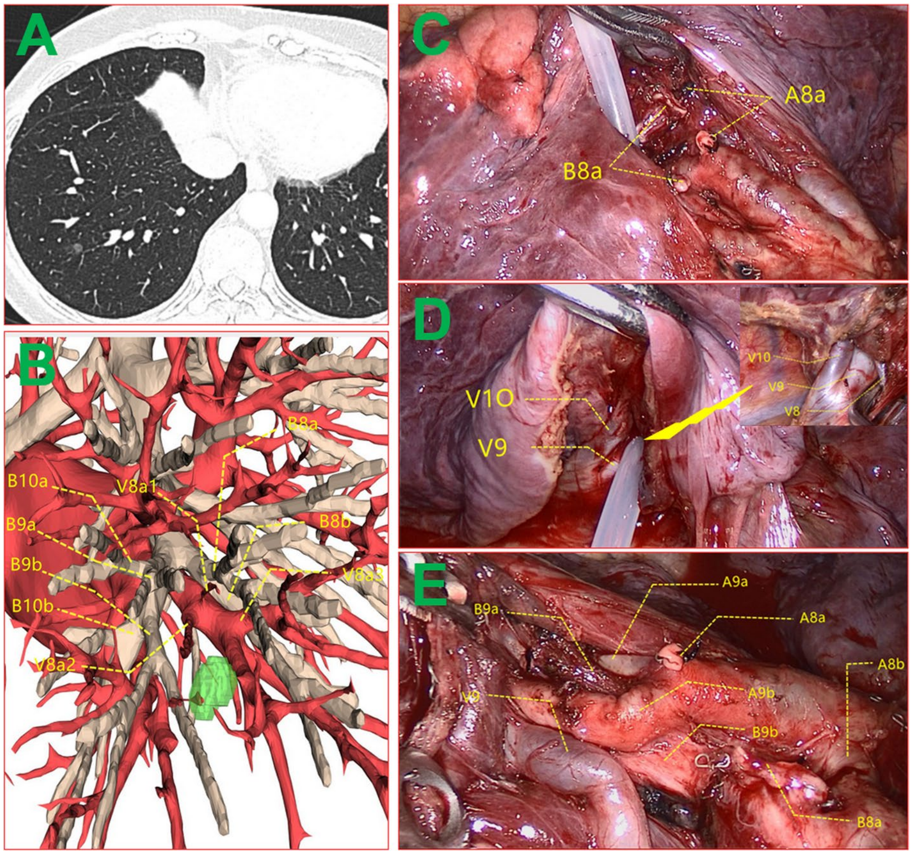

Fig. 6 Radiological images and surgical procedure images of a right lower lobe lung nodule. (**A**) Lung window obtained via computed tomography; (**B**) Three-dimensional image of the bronchography and vasculature obtained via computed tomography; (**C**) Tunneling hatchway 1; (**D**) Tunneling hatchway 2; (**E**) Surgical field after creating a fissure by tunneling techniques with precise resection of lung segments

These lung nodules in complex positions involving intersegmental and multisegmental regions, such as lung nodules are located in the inner-middle third lung field LS3, LS2, and LS1; RS1 and S3a; RS1b, S2b and S3a; RS1b and S3a; RS8a and S9; RS6 and S9. Seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments cannot be easily understood but can be explained by this approach. To explain this technique, we must mention the thoracoscopic tunnel technique. It was originally developed by Katsuyuki Endo in the 1990s and is called the "tunneling stapler technique" [22]. Consequently, how to comprehend the tunneling technique and create a tunnel during surgical thoracic operation actually correspond to three stages. First, when performing lobectomy on a patient with an incomplete interlobar fissure, the tunnel technique is utilized if the interlobar fissure approach is still preferred [5, 23, 24]. Second, distinct gaps can be observed between the superior segment and the basal segment, as well as between the lingular segment and the intrinsic segment, even in the absence of a fissure. Additionally, the spaces between RS3 and RS1 + RS2, LS3 and LS1 + 2, and S9 + S10 and S7 + S8/S7 + 8 may also be anatomically separated by tunneling techniques [25]. These potential spaces also be anatomically separated in some cases though creating a fissure by tunneling techniques [24, 25], such as cases at this study.

This expands the scope of lung segmentectomy for patients with lung nodules in complex positions involving multiple segments. Avoiding the removal of additional lung tissue to protect lung function (only a small part of the lung lobe is removed) is conducive to postoperative rehabilitation. Moreover, we have noted the implementation of this type of segmentectomy had a threshold for the location, size and CTR of the nodule. Of course, not all lung nodules need to be removed. Only those lung nodules that are highly suspected of being cancerous should be considered for treatment.

Seeking anatomical conditions for creating a fissure by tunneling techniques highlights its anatomy. After all, the spaces between RS3 and RS1 + RS2, LS3 and LS1 + 2, and S9 + S10 and S7 + S8/S7 + 8 is minimal. So, accurate 3D reconstruction results and a skilled anatomical basis for the surgeon are needed. In the tunneling approach, it is

Table 1 The baseline characteristics and surgical outcomes of segment group versus lobectomy group

Variable	Total *N* = 69	Segment group *N* = 22	Lobectomy group *N* = 47	*P*
Age (year)	56.19 ± 10.71	52.59 ± 11.27	57.87 ± 10.13	0.056
Sex (m/f)	23/46	7/15	16/31	0.855
Smoking (no/yes)	47/22	15/7	32/15	0.9936
Comorbidity* (no/yes)	57/12	17/5	40/7	0.5010
Heart disease	52/17	17/5	35/12	0.8011
Copd	58/11	18/4	40/7	0.7345
Diabetes	49/20	16/6	33/14	0.8301
Hypertension	59/10	18/4	41/6	0.7152
Cerebrovascular				
Tumor size (cm)	1.32 ± 0.40	0.98 ± 0.31	1.49 ± 0.34	< 0.001
Ctr	0.41 ± 0.31	0.27 ± 0.19	0.47 ± 0.33	0.003
Position	21	6	15	0.841
rul	12	4	8	
rll	27	8	19	
lul	9	4	5	
lll				
Nodule type	25	10	15	0.276
pggo	44	12	32	
mggo				
Depth ratio	0.52 ± 0.14	0.43 ± 0.13	0.56 ± 0.13	< 0.001
Pathology results	10	10	0	< 0.001
ais or others noncancerous nodule	12	8	4	
mia	47	4	43	
iac				
Surgical margin (cm)		2.15 ± 0.31		
Operative time (min)	131.55 ± 38.48	146.91 ± 47.04	124.36 ± 31.83	0.050
Intraoperative drainage (ml)	47.10 ± 31.63	44.55 ± 26.68	48.30 ± 33.90	0.649
Postoperative hospital stays (day)	4.30 ± 1.95	3.36 ± 0.66	4.74 ± 2.19	< 0.001
Air leakage (no/yes)	65/4	20/2	45/2	0.956

Ctr consolidation tumor ratio, *rul* right upper lung, *rll* right lower lung, *lul* left upper lung, *lll* left lower lung, *ais* adenocarcinoma in situ, *mia* minimally invasive adenocarcinoma, *iac* invasive adenocarcinoma cancer,

* had been hospitalized for the disease or had been treated by uninterrupted treatment more than 2 weeks

† prolonged air leak > 12 h

crucial to accurately identify hatchway 1 and hatchway 2. Once the two hatchways are identified correctly, the tunneling technique allows the surgeon to perform a deep dissection of the arteries to precisely identify the subsegmental branches and thus avoid misidentification. Then, the target arteries and bronchus of the target segment and the adjacent segment were exposed. An additional advantage of the tunneling technique is that early division of the intersegmental plane significantly facilitates completion of the division of the intersegmental plane of the adjacent lung subsegment [25]. After obtaining such an anatomical plane extension, precise anatomical details such as lung subsegments, surgical margins, and intrapulmonary lymph nodes are exposed to the visual field. Here, this tunneling technique presented the new concept of atypical segmentectomy, which centers on the lesion to obtain adequate surgical margins. The location of the tumor determines the surgical type. Sufficient surgical margins were obtained in all patients in this study.

In our experience, our data analysis revealed that there are prerequisites for implementing the tunneling technique at these complex setting. The patients were selected if they had an early pathological stage, a small tumor diameter, or a depth ratio that was not deep. Firstly, our indications for segmentectomy were strictly controlled, and we did not select patients who were considered to have no benefit in the JCOG0802 study. Secondly, in the early period of this technique, we were slightly conservative in our selection of patients. Due to a poor medical environment, lobectomy was not guaranteed. Now, that attitude has gradually changed, the technology has matured, and confidence has increased. At the technical maturity stage, in patients with a tumor diameter of 1.7 cm, a CTR of 60% and a pathological type of invasive adenocarcinoma, we also performed satisfactorily this tunneling technique with a surgical margin of 2 cm. Thirdly, tunneling technique at these complex setting also has certain requirements for the position of lung

Table 2 Baseline Characteristics of Patients with seeking anatomical conditions for creating a fissure by tunneling techniques with precise resection of lung segments at complex setting

Patient	Age (years)	Sex	Area of resection	Tumor size (cm)	Depth ratio	CTR	Pathology	Surgical margin (cm)
1	43	male	LS1 + 2c + S3a	0.6	0.46	0.30	1	2.0
2	41	male	RS9	0.6	0.46	0.40	1	2.0
3	56	female	LS9	1.2	0.59	0.40	1	1.8
4	55	female	LS9	1.0	0.30	0.36	3	2.0
5	65	female	LS1 + 2c + S3a	0.9	0.53	0.20	2	2.0
6	48	male	RS1 + S3a	1.0	0.32	0.14	1	2.2
7	61	male	RS9	1.5	0.50	0.10	3	2.0
8	34	male	LS1 + 2c + S3a	0.7	0.28	0.60	1	3.0
9	55	female	LS1 + 2c + S3	1.3	0.43	0.10	1	3.0
10	41	female	RS1 + S3a	0.6	0.67	0.10	2	2.0
11	73	male	LS3a + b	1.1	0.32	0.10	1	2.5
12	46	female	RS8a + S9	1.1	0.45	0.30	2	2.3
13	58	male	RS1b + S3a	1.3	0.31	0.60	3	2.0
14	58	female	LS1 + 2c + S3	0.7	0.46	0.30	2	2.0
15	50	female	LS3	1.0	0.50	0.10	1	2.0
16	44	female	RS6 + S9	1.0	0.38	0.10	2	2.2
17	71	female	LS9	1.7	0.75	0.60	3	2.0
18	33	female	RS1 + S3a	0.8	0.17	0.10	2	2.0
19	51	female	RS1 + S3a	0.7	0.37	0.60	2	2.3
20	48	female	LS9	0.9	0.40	0.10	1	2.0
21	55	female	RS1b + S2b + S3a	0.6	0.43	0.20	1	2.0
22	71	female	LS1 + 2c + S3a	1.2	0.38	0.20	2	2.0

1 = adenocarcinoma in situ or others noncancerous nodule; 2 = minimally invasive adenocarcinoma; 3 = invasive adenocarcinoma cancer

nodules. When the nodule is located in the inner third lung field, satisfying the surgical margin may damage the arteriovenous space of the hilar. However, when the nodules are located in the outer third lung field, wedge resection of the lung may be used to achieve good surgical results.

Considering the complexity of the procedure and the presence of more than one intricate intersegmental plane, creating a fissure by tunneling techniques with precise resection of lung segments is considered complex. Special anatomical marks, V6, A8, A1 + 2c, A2b, A3b, the lingual vein and the bronchus has a good guide to the hatchways [26–29].

Limitations

This was not a prospective randomized controlled study because of the necessity of reviewing the specifics of surgical video replays. To mitigate confounding factors, the study exclusively enrolled patients who underwent surgeries at a single center and who underwent a single operation. What's more, the patients were selected if they had an early pathological stage, a small tumor diameter, or a depth ratio that was not deep. In fact, this study was based on empirical descriptive research. Consequently, the generalizability and applicability of the study's findings may be subject to some deviation.

Conclusions

In conclusion, seeking anatomical conditions for creating a fissure by tunneling techniques is a promising technique for performing precise resection of lung segments with a safe resection margin for patients with lung nodules at complex positions involving multiple segments, and it can reduce the count of resected subsegments. Furthermore, patients experienced expedited postoperative recuperation. In addition, the tunneling technique facilitates clearer visualization of the hilus structure, which includes the lung vessels and bronchus.

Abbreviations

LCSG	Lung Cancer Study Group
CT	Computerized tomography
3D	Three-dimensional
CTR	Consolidation tumor ratio
RUL	Right upper lung
RLL	Right lower lung
LUL	Left upper lung
LLL	Left lower lung
AIS	Adenocarcinoma in situ

MIA Minimally invasive adenocarcinoma
IAC Invasive adenocarcinoma cancer

Authors' contributions
(I) Conception and design: JZ, WW, LC and ZC; (II) Administrative support: LC; (III) Provision of study materials or patients: JNZ, KW and ZL; (IV) Collection and assembly of data and interpretation: KC JNZ, KW, ZL and WW; (V) Manuscript writing, data analysis, figures and tables making: JZ; (VI) Manuscript review and final approval of manuscript: All authors.

Funding
This work is supported by grants from the Young Scholars Plan with Growth Project of General Hospital of Central Theater Command of the People's Liberation Army (2023–1692), and the Science & Technology Developing Programme Research of Henan Province (242102310101).

Data availability
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of First Affiliated Hospital of Nanjing Medical University (2021-SR-164), with all procedures performed in accordance with ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. No other ethical statement is required. Due to the retrospective nature of this study, which did not involve experiments on humans and/or the use of human tissue samples, the requirement for informed consent was waived, contingent upon the anonymization of patient data. The clinical trial number is not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 12 October 2024 Accepted: 10 December 2024
Published online: 21 December 2024

References
1. Ginsberg RJ, Rubinstein L. The comparison of limited resection to lobectomy for T1N0 non-small cell lung cancer. LCSG 821. Chest. 1994;106(6):318S-319S.
2. Jang HJ, Lee KS, Kwon OJ, et al. Bronchioloalveolar carcinoma: focal area of ground-glass attenuation at thin-section CT as an early sign. Radiology. 1996;199(2):485–8. https://doi.org/10.1148/radiology.199.2.8668800.
3. Wu XY, Ding F, Li K, Huang WC, et al. Analysis of the Causes of Solitary Pulmonary Nodule Misdiagnosed as Lung Cancer by Using Artificial Intelligence: A Retrospective Study at a Single Center. Diagnostics (Basel). 2022;12(9):2218. https://doi.org/10.3390/diagnostics12092218.
4. Wu WB, Xu XF, Wen W, et al. Thoracoscopic Pulmonary Sub-Subsegmentectomy Based on Three-Dimensional Images. Ann Thorac Surg. 2016;102(5):e389–91. https://doi.org/10.1016/j.athoracsur.2016.04.048.
5. Zhu SS, Zheng J, Chen L, et al. The safety and efficacy of the fissure-first approach in lung segmentectomy for patients with incomplete fissures. Front Oncol. 2024;14:1391835. https://doi.org/10.3389/fonc.2024.1391835.
6. Altorki NK, Wang X, Wigle D, et al. Perioperative mortality and morbidity after sublobar versus lobar resection for early-stage non-small cell lung cancer: post hoc analysis of an international, randomized, phase 3 trial (CALGB/Alliance 140503). Lancet Respir Med. 2018;6(12):915–24. https://doi.org/10.1016/S2213-2600(18)30411-9.
7. Saji H, Okada M, Tsuboi M, et al. Segmentectomy versus lobectomy in small-sized peripheral non-small cell lung cancer (JCOG0802/WJOG4607L): a multi center, open-label, phase 3, randomized, controlled, noninferiority trial. Lancet. 2022;399(10335):1607–17. https://doi.org/10.1016/S0140-6736(21)02333-3.
8. Yoshino I, Moriya Y, Suzuki K, et al. Long-term outcome of patients with peripheral ground-glass opacity-dominant lung cancer after sublobar resections. J Thorac Cardiovasc Surg. 2023;166(4):1222-1231.e1. https://doi.org/10.1016/j.jtcvs.2023.01.019.
9. Weiss KD, Deeb AL, Wee JO, et al. When a segmentectomy is not a segmentectomy: Quality assurance audit and evaluation of required elements for an anatomic segmentectomy. J Thorac Cardiovasc Surg. 2023;165(6):1919–25. https://doi.org/10.1016/j.jtcvs.2022.08.042.
10. He Z, Wu W, Chen L. A "true segmentectomy" cannot be overemphasized especially in the complex setting. Interdiscip Cardiovasc Thorac Surg. 2023;36(5):ivad075. https://doi.org/10.1093/icvts/ivad075.
11. Zhang M, Mao N, Wu QC, Ge MJ. A novel method for distinguishing the intersegmental plane: pulmonary circulation single-blocking. J Thorac Dis. 2021;13(1):362–5. https://doi.org/10.21037/jtd-20-3428.
12. Onodera K, Suzuki J, Miyoshi T, et al. Comparison of various lung intersegmental plane identification methods. Gen Thorac Cardiovasc Surg. 2023;71(2):90–7. https://doi.org/10.1007/s11748-022-01885-5.
13. Wang J, Xu X, Wen W, et al. Technique for tailoring complex demarcation in lung segmentectomy. Thorac Cancer. 2018;9(11):1562–4. https://doi.org/10.1111/1759-7714.12864.
14. Chang SS, Yokomise H, Yokota N, et al. Dual Image Navigation to Secure Surgical Margins in Thoracoscopic Segmentectomy. Ann Surg Oncol. 2023;30(2):843–9. https://doi.org/10.1245/s10434-022-12615-9.
15. Huang J, Bian C, Zhang W, et al. Partitioning the lung field based on the depth ratio in three-dimensional space. Transl Lung Cancer Res. 2022;11(6):1165–75. https://doi.org/10.21037/tlcr-22-391.
16. Nakazawa S, Hanawa R, Nagashima T, et al. Segmentectomy Guided by 3-Dimensional Images Reconstructed From Nonenhanced Computed Tomographic Data. Ann Thorac Surg. 2021;111(4):e301–4. https://doi.org/10.1016/j.athoracsur.2020.07.098.
17. Berfield KS, Afolayan OA, Wood DE. Management of Small Lung Nodules in the Era of Lung Cancer Screening. JAMA Surg. 2019;154(4):303–4.
18. Liu L, Aokage K, Chen C, et al. Asia expert consensus on segmentectomy in non-small cell lung cancer: A modified Delphi study. JTCVS Open. 2023;14:483–501. https://doi.org/10.1016/j.xjon.2023.03.013.
19. Heiden BT, Eaton DB Jr, Chang SH, et al. Association Between Surgical Quality Metric Adherence and Overall Survival Among US Veterans With Early-Stage Non-Small Cell Lung Cancer. JAMA Surg. 2023;158(3):293–301. https://doi.org/10.1001/jamasurg.2022.6826.
20. Li Z, Xu W, Wang J, et al. Three-Dimensional Guided Cone-Shaped Segmentectomy Versus Lobectomy for Small-sized Non-Small Cell Lung Cancer in the Middle Third of the Lung Field. Ann Surg Oncol. 2023;30(11):6684–92. https://doi.org/10.1245/s10434-023-13772-1.
21. Li Z, Xu W, Pan X, et al. Segmentectomy versus lobectomy for small-sized pure solid non-small cell lung cancer. Thorac Cancer. 2023;14(11):1021–8. https://doi.org/10.1111/1759-7714.14840.
22. Kobayashi N, Endo K. Pulmonary segmentectomy with tunneling stapler technique. Thorac Cardiovasc Surg. 2014;62(8):722–4. https://doi.org/10.1055/s-0034-1389271.
23. Wu WB, Xu XF, Wen W, et al. Three-dimensional computed tomography bronchography and angiography in the preoperative evaluation of thoracoscopic segmentectomy and subsegmentectomy. J Thorac Dis. 2016;8(Suppl 9):S710–5. https://doi.org/10.21037/jtd.2016.09.43.
24. Ojanguren A, Forster C, Gonzalez M. Uniportal VATS fissure-based approach to segments 9 and 10. Multimed Man Cardiothorac Surg. 2020;2020. https://doi.org/10.1510/mmcts.2020.041.
25. Zhu J, Fu CH, Chen L, et al. Unveiling the synergetic benefits of the tunneling technique using stapler tractor in precise resection of lung

segments: a retrospective cohort study. Front Oncol. 2024;14:1417871. https://doi.org/10.3389/fonc.2024.1417871.
26. Xu XF, Chen L, Wu WB, Zhu Q. Thoracoscopic right posterior segmentectomy of a patient with anomalous bronchus and pulmonary vein. Ann Thorac Surg. 2014;98(6):e127–9. https://doi.org/10.1016/j.athoracsur.2014.09.059.
27. Xu X, Wang J, Liu Q, et al. Clinical significance of the diverse interlobar veins hidden in the upper oblique fissure. Ann Transl Med. 2022;10(2):34. https://doi.org/10.21037/atm-21-4913.
28. Hong R, Chen C, Zheng W, et al. "Split" combined subsegmentectomy: A case series. Thorac Cancer. 2022;13(3):423–9. https://doi.org/10.1111/1759-7714.14275.
29. Wang J, Lin H, Bian C, et al. A modified system for classifying the bilateral superior pulmonary veins using three-dimensional computed tomography bronchography and angiography images. J Thorac Dis. 2021;13(10):5933–41. https://doi.org/10.21037/jtd-21-985.

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