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Individualized dorsal basal segment (S^{10}) resection using intersegmental veins as the landmark

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Key question

What is the ideal resection range for S^{10}-predominated nodules with safe margins and how do you technically remove them?

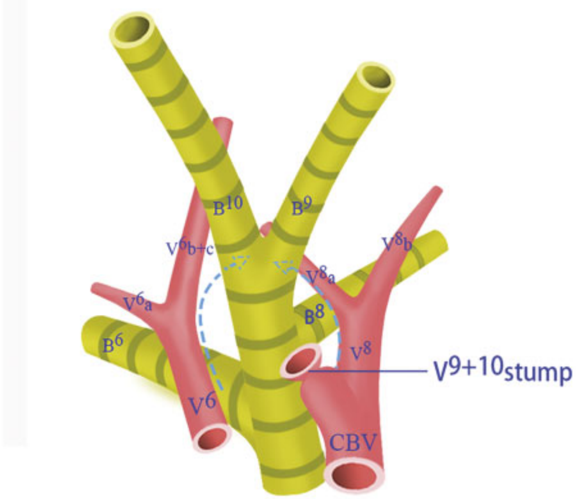
Key finding(s)

The intersegmental vein could help operation simulation, target bronchial recognition and intersegmental plane division.

Take-home message

The intersegmental vein may facilitate individualized S^{10} resections. The potential benefit of reducing complications needs further study.

Schematic of the inter-SV guided right S^{9+10} resection. Dissecting along inter-SVs(V^8,V^8a,V^6(b+c)) facilitates B^{9+10} recognition.



Abstract

OBJECTIVES: The individualized thoracoscopic dorsal basal (S^{10}) resection remains one of the most challenging procedures. Our goal was to detail the role of intersegmental veins (inter-SVs) in facilitating such a complex operation and evaluate its safety and efficacy.

METHODS: We retrospectively reviewed patients who underwent S^{10} or S^{10} plus an adjacent segment or subsegment resection (individualized S^{10}) from January 2015 through September 2020. Individualized S^{10} resections were conducted for nodules of 2 cm or less with a ground-glass opacity evident in thin-slice computed tomography. A simplified method of using inter-SVs as the landmark in surgical planning and segmentectomy was described. The efficacy and safety of this technique were also evaluated in comparison with those aspects of the lower lobectomy.

[†]The first two authors contributed equally to this work.

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RESULTS: In total, 46 patients who underwent individualized S^{10} through an inferior pulmonary ligament approach were included. All patients received R_0 resection with a surgical margin of 22.45 mm. No patient was converted to an extended resection such as an entire basal or lower lobar resection. Three patients whose situation was complicated with an air leak had non-urgent interventions. Comparable results were obtained between the segmental and lobar arms in terms of blood loss (49.13 vs 45.98 ml), postoperative hospital stay (4.96 vs 5.18 days) and persistent air leak (6.52% vs 4.01%).

CONCLUSIONS: A strategy guided by the inter-SVs permits one to tailor the surgical planning for S^{10} nodules without compromising the surgical margin. It could also facilitate target bronchial recognition and intersegmental plane division. However, long-term follow-up and large clinical studies are needed to further justify its clinical benefits.

Keywords: Individualized dorsal basal (S^{10}) resection • Intersegmental vein • Surgical planning • Bronchial recognition • Complications

ABBREVIATIONS

3D	Three-dimensional
3D-CTBA	Three-dimensional CT bronchography and angiography
GGO	Ground-glass opacities
inter-SVs	Intersegmental veins

INTRODUCTION

Sublobar resection for the treatment of early-stage lung cancer has recently gained tremendous interest within the thoracic community. As shown at the First International Conference on Sublobar Resection for Lung Cancer in 2018, more than 230 thoracic surgeons from 33 countries got involved [1]. The historical data from the Lung Cancer Study Group [2] have recently been challenged by contemporary retrospective studies. The sublobar resection, especially the segmentectomy, has showed equivalent oncological outcomes and better pulmonary functional preservation than lobar resection for small ground-glass opacities (GGO) [3, 4]. Nowadays, sublobar resection has been widely performed on patients with early-stage primary lung cancer, metastatic lung cancer and some undiagnosed pulmonary nodules [5, 6].

Thoracoscopic removal of dorsal basal segment (S^{10}) nodules has rarely been reported [7–10]. For some nodules predominately located at S^{10} but much closer to the border of S^9 or S^6, single S^{10} resection cannot ensure a safe surgical margin (≥2 cm or the maximal diameter of the nodule). In this situation, S^{10} plus an adjacent segment or subsegment (individualized S^{10}) may be a wiser option. We previously reported how we categorized pulmonary nodules into different types based on the relationship of the nodules and vessels in three-dimensional (3D) CT bronchography and angiography (3D-CTBA) [11]. Nevertheless, how to technically remove such nodules has not been described in detail.

A segmentectomy was recently subdivided into simple and complex segmentectomies based on the number and shape of the intersegmental planes. A complex segmentectomy was categorized as one with several intricate or multidimensional interfaces between segments [12]. From this perspective, an individualized S^{10} resection is deemed to be one of the most complex operations [13]. The complexity of the individualized S^{10} resection is also reflected in the following perspectives: First, accurate transection of bronchi is critical because they are deep in the hilum and cannot be easily reached either through an interlobar approach or an inferior pulmonary ligament approach [7–10]. Second, when thoracoscopic individualized S^{10} resection is initially started from the latter approach and the ligament is retracted in a cranial direction, disorientation of the bronchi could easily happen under thoracoscopic visualization [9]. The real anatomical relationship is upside down in the real operative view. Finally, the potential existence of anatomical variations makes it more difficult to identify the target bronchi.

In these scenarios, the role of the intersegmental veins (inter-SVs) has rarely been addressed. In 1949, Ramsay [14] named the 'intersegmental vein' and, for the first time, regarded it as the landmark for dividing the intersegmental plane. Boyden [15] in 1945 clarified in detail that these veins peripherally drain blood from adjacent segments and anatomically occupy the intersegmental planes. In 1889, Ewart [16] described their characteristics as those of a pulmonary vein. 'They generally select the middle of the interspace which intervenes between 2 or several bronchi'. Previous studies emphasized that the anatomical course of inter-SVs and the demarcation of intersegmental planes are basically the same in the pulmonary parenchyma [17]. Few investigators have expounded the anatomical relationship between the inter-SVs and the bronchi at the hilum.

Our goal was to report our initial experiences with individualized resections for tough S^{10} nodules based on the anatomical relationship of the target nodule and the corresponding inter-SVs. We assumed that this concept could help surgical planning and facilitate recognition of the target bronchi and division of the intersegmental plane.

PATIENTS AND METHODS

Patients

A total of 46 patients undergoing thoracoscopic removal of S^{10} nodules who fulfilled the following criteria were enrolled in this study from January 2015 to September 2020: (i) undetermined pulmonary nodules but highly suspected of malignancy and (ii) primary lung cancer ≤2 cm in maximal diameter, ratio of GGO ≥50% in thin-slice CT. The method of using inter-SVs as the landmark was preferably applied in all cases.

To evaluate the safety and efficacy of this technique, we also retrieved the data of 274 patients who underwent right or left lower lobectomy for small pulmonary nodules (≤2 cm) during the same period as a reference. Lobectomy was specifically considered for some deeply located small nodules. In those instances, the margin was more likely to be insufficient or positive if segmentectomy was applied. The ratio of GGO is another factor. For those solid-dominated nodules, we performed a lobectomy instead of a segmentectomy despite the small size of the nodules (≤2 cm).

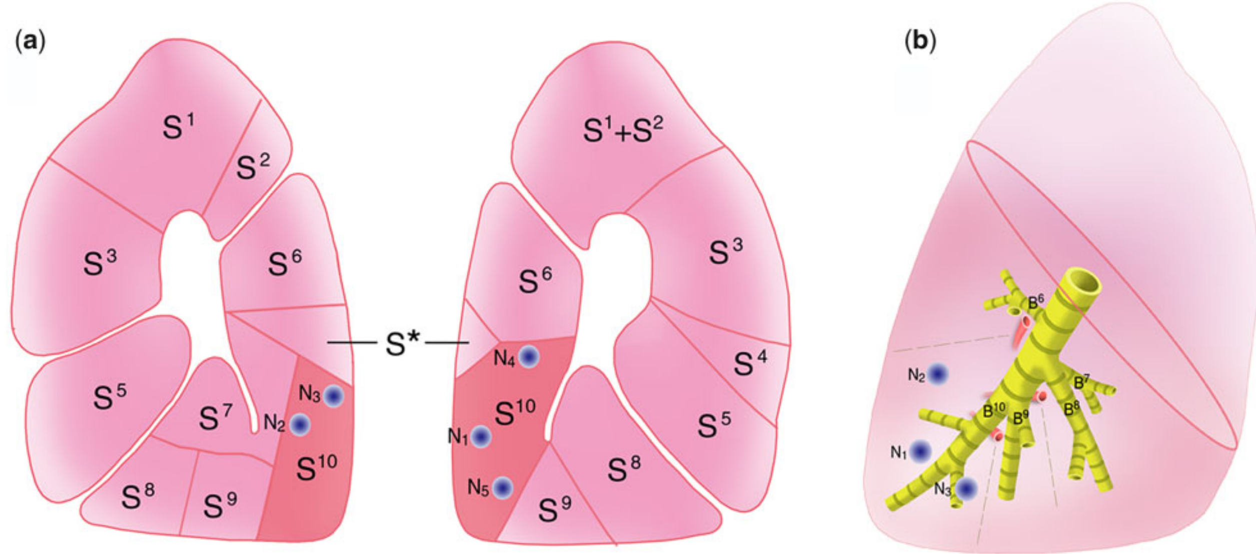


Figure 1: Indication for single S^{10} or complex S^{10} segmentectomy. (**a**) Schematic of lung segments (S) on both sides and nodules (N). N_1 is located far away from the borders of the adjacent segments, appropriate for a single S^{10} resection, but $N_{2–5}$ are different. For instance, an S^{10} plus an S^7 or S^7b resection is indicated for N_2, and an S^{10} plus a subsuperior segment (S*) resection is indicated for N_3 if S* is obviously there. Otherwise, S^{10} plus a subsegment of S^6 resection is indicated (for N_4). S^{10} plus an S^9 resection is appropriate for N_5. Occasionally, B^9a branches from the common trunk of B^{9+10}; S^{10} plus an S^9b resection is an alternative option. (**b**) Schematic of right lower lobe segments and nodules (N) using the intersegmental veins as the landmark. The intersegmental veins are always in accordance with the intersegmental plane (dashed line). N_1 is appropriated for a single S^{10} resection, but S^{10} plus an adjacent subsegment or segment resections should be considered for N_2 and N_3.

Given the location of the nodules and the size of the tumour, patients with wedge resection, removal of multiple nodules or extended S^{10} segmentectomies were not enrolled in this cohort.

Two authors (Zhicheng He and Xianglong Pan) independently reviewed all patient data. One senior surgeon (Liang Chen) was responsible for quality control and reviewed all the recorded videos. Any discrepancy was discussed and resolved within the team.

Nomenclature and numbering of pulmonary segments and subdivisions were used in accordance with the *Roentgenologic Anatomy of the Lung* [18].

Ethics statement

The protocol of the surgical procedure and study was approved by the research ethics committee of the First Affiliated Hospital of Nanjing Medical University (2020-SR-441). Written informed consent from each patient was obtained prior to the operation.

Three-dimensional computed tomographic bronchography and angiography

The 3D-CTBA was routinely created by using our self-developed software 'DeepInsight' or Materialise's interactive medical image control system (Materialise, Leuven, Belgium). After injection of contrast medium (Ultravist, Bayer Schering, Berlin, Germany), multidetector CT images were recorded with 1-mm data slices (Definition, Siemens, Munich, Germany) and saved in the Digital Imaging and Communications in Medicine standard format. The reconstructions of the bronchi and vessels were processed preoperatively. Magnifying, demagnifying or rotating the area of interest in the 3D image allowed the surgeons to localize the nodule and distinguish the target segmental structures.

Surgical planning

The candidates for single S^{10} resection were patients with the nodules within S^{10} and far away from the corresponding inter-SVs in 3D-CTBA. In cases of nodules predominately located in S^{10} but much closer to the inter-SVs, S^{10} plus an adjacent segment or subsegment resection was indicated in order to obtain a safe surgical margin (Fig. 1).

The method of determining the surgical margin was described previously [11]. The surgical procedure was simulated based on nodule location and margin distance in the 3D-CTBA. The least 2 cm or the maximal diameter of the nodules was designed to obtain a safe margin. A default value of 2 cm was routinely set in the 3D reconstruction software to show the virtual margin, which was demonstrated as a yellow sphere, extending 2 cm outside the target nodule. The assumed intersegmental plane was always in accordance with the inter-SVs (Fig. 2). In cases in which the inter-SVs happened to be running through the 'yellow sphere', this assumed plane was not sufficient to obtain a safe margin. Thus, S^{10} plus an adjacent segment or subsegment resection was performed instead.

Surgical technique

Patients were placed in the lateral decubitus position under general anaesthesia with single lung ventilation. The chest cavity was thoracoscopically accessed with 3 ports. Digital palpation was not routinely used because the nodules were deeply located. This procedure required thorough procedure simulation prior to the operation and a decision as to which segment or subsegment the target nodule belonged to. The procedures were preferably initiated with dissection of the inferior pulmonary ligament, followed by exposure of the inferior pulmonary vein and its branches. The landmark of the inter-SV was identified and exposed in a stem-

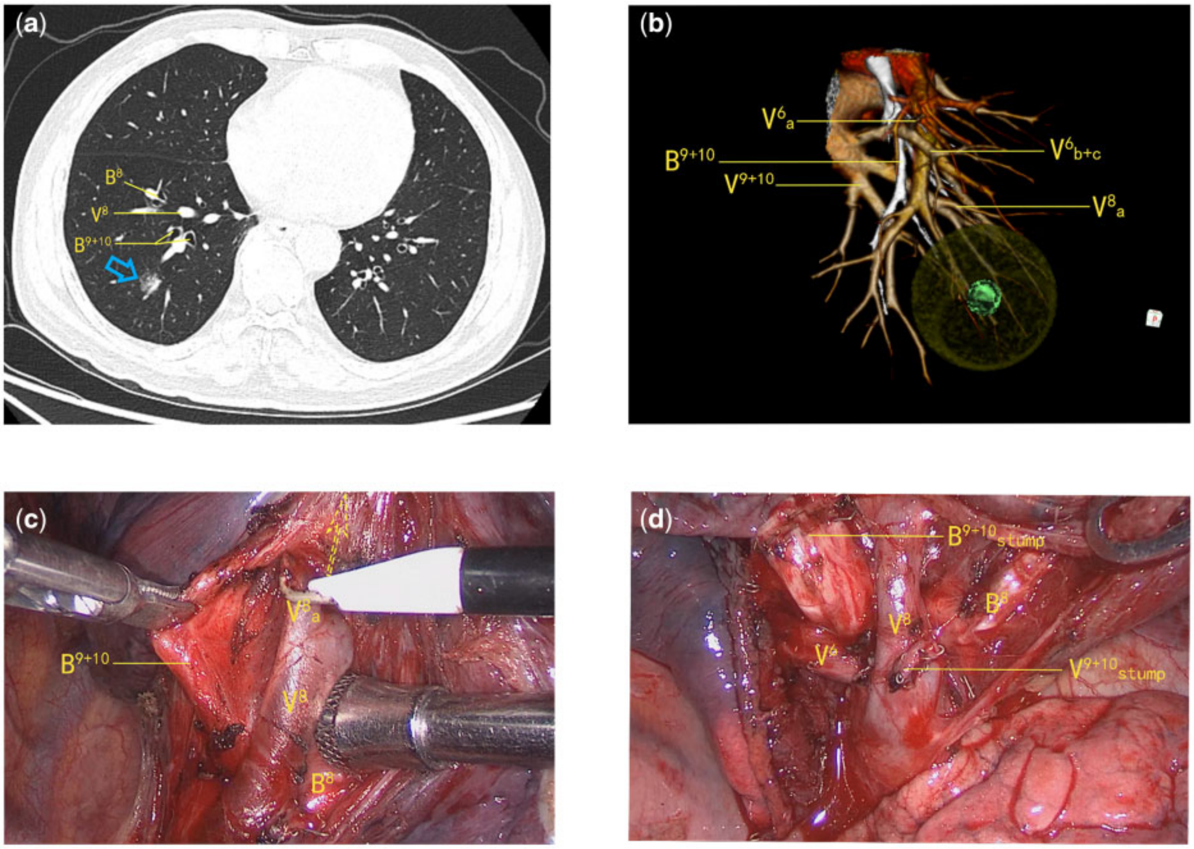


Figure 2: A representative case of the right S^{9+10} resection. (**a**) The computed tomography scan shows a mixed ground-glass opacity (blue arrowhead) in the right lower lobe, ~1.4 cm, 2.7 cm away from the lung surface. (**b**) The three-dimensional computed tomographic bronchography and angiography scan marks the target nodule (green solid ball) with a 2-cm virtual margin. The light-yellow ball wrapping the target nodule represents the margin. (**c**) The inferior pulmonary ligament is initially isolated, followed by transection of the V^{9+10}. Then, we dissect along the V^8 and V^8a, which run anteriorly and medially to the B^{9+10} until they are clearly exposed. V6 contains branches of V^6a and V^6(b + c). The latter, running posteriorly and laterally to the B^{9+10}, are exposed in the same fashion (not presented). By using V^8, V^8a and V^6(b + c) as the landmarks, the intersegmental veins are dissected in the stem-to-branch fashion to guide recognition of B^{9+10}. B^8 and B^6 are easily recognized and preserved because they run outside the intersegmental veins. Afterwards, V8 also guides orientation of the dissection of the intersegmental plane between S^8 and S^{9+10} (yellow dash arrow). (**d**) The intraoperative view shows the courses of the intersegmental veins. They help recognize the B^{9+10} and the preserved B^8 and B^6 (not shown). B^{9+10}: lateral dorsal basal bronchus; B^8: ventral basal bronchus; B^6: superior bronchus; S^{9+10}: lateral dorsal basal segment; S^8: ventral basal segment; V^8: intersegmental vein running between the ventral (S^8) and lateral basal segments (S^9), arising from the basal vein trunk, giving rise to 2 branches—V^8a and V^8b. V^6: superior distribution of the inferior pulmonary vein, giving rise to 3 branches V^6a, V^6b and V^6c, V^6(b + c) usually coursing in the common trunk between the superior segment (S^6) and the basal segments.

to-branch fashion. We used the right S^{9+10} (Fig. 2) and left $S^{10}+S^6$c resection (Fig. 3 and Video 1) as examples to demonstrate in detail the surgical planning and techniques. If the result from the intraoperative frozen section of the lymph node was positive, a lobectomy and systematic nodal dissection were performed.

Statistical analyses

The Student's *t*-test was used for continuous variables (age, tumour size, operative time, blood loss, lymph nodes examined and length of postoperative stay), whereas the χ^2 test or the Fisher exact test was adopted for categorical variables. For categorical variables with expected events <5 but >1, the χ^2 test with Yates' continuity correction was used. The Fisher exact test was adopted when the number of cells with expected events <5 accounted for more than 1/5 of the total cells. Continuous variables were shown as mean ± standard deviation. All the analyses were performed using R (3.6.0), and $P < 0.05$ was considered statistically significant.

RESULTS

The different types of individualized S^{10} segmentectomies (seg. arm) through the inferior pulmonary ligament approach are listed in Table 1. $S^{10}+S^9$ was the most prevalent type followed by single S^{10}.

In total, 18 male and 28 female patients, ranging in age from 28 to 75 years (mean, 53.00 years), were included in the seg. arm. A satisfactory margin was obtained (22.45 ± 3.38 mm). Adenocarcinoma in situ was pathologically confirmed in 6 patients, minimally invasive adenocarcinoma in 11, invasive adenocarcinoma in 24 and benign in 5. Tumour size ranged from 7.3 to 22.1 mm (mean, 10.13 mm). The mean operative time was 177.00 min with a mean blood loss of 49.13 ml. The mean postoperative hospital stay was 4.96 days. No patient required conversion to extended resection such as the entire basal or lower lobar resection.

To evaluate the efficacy and safety, we also reviewed clinical data regarding patients who were allocated to a lower lobectomy for small nodules (≲2 cm) during the same period in our centre (Table 2). A total of 274 patients were finally selected as a reference

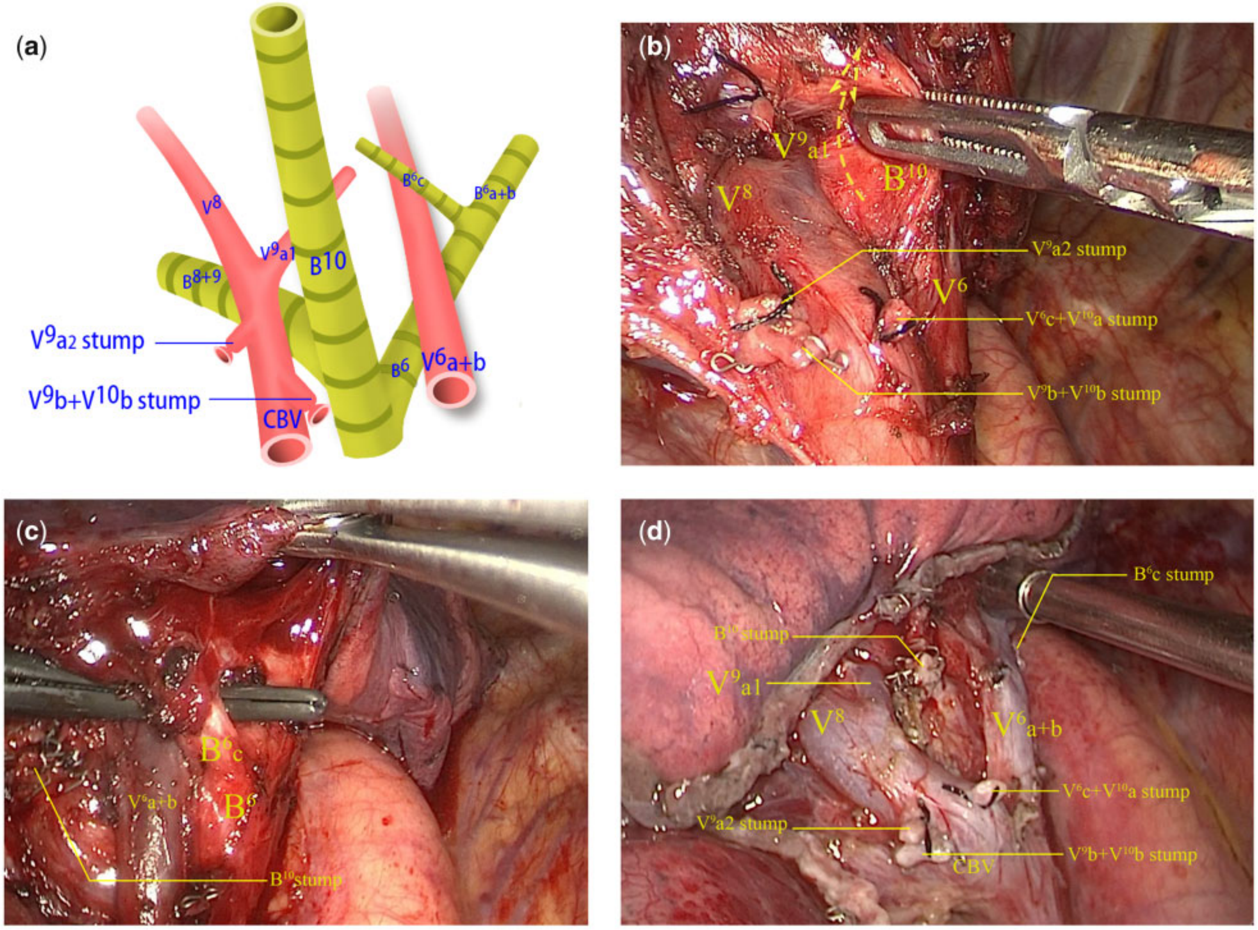


Figure 3: Key techniques in a left $S^{10}+S^6c$ resection. (**a**) Schematic of the intersegmental vein-guided left $S^{10}+S^6c$ resection. The V^9a1 helps the recognition of B^{10}. Similarly, dissection along the V^6a+b facilitates B^6c recognition. Both intersegmental veins provide landmarks in the left $S^{10}+S^6c$ resection. (**b**) The V^9a1 guides the recognition and transection of B^{10}. A right-angle clamp is placed along the surface of V^9a1 to help B^{10} transection (yellow dash arrowhead). (**c**) The V^6a+b guides B^6c recognition and transection. Dissection along V^6a+b is continued in a stem-to-branch fashion. The B^6c is encountered as it runs over the V^6a+b. A right-angle clamp is then placed along the surface of V^6a+b to help the transection of B^6c. (**d**) The intraoperative view of the hilar structures. B^{10}: dorsal basal bronchus; S^{10}: dorsal basal segment; S^6c: medial subsegment of superior segment (S^6); B^6c: medial subsegmental bronchus of superior segment (S^6); V^9a1: running between lateral subsegment of lateral basal segment (S^9a) and dorsal subsegment of S^{10}($S^{10}a$); V^6a+b: running between S^6a+b and S^6c.

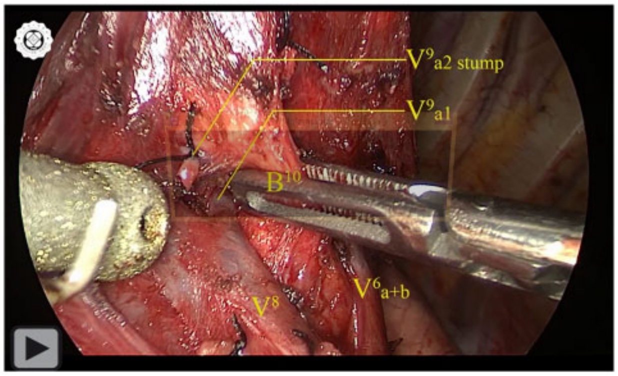
(lob. arm). With regards to the complications, blood loss (0.654), persistent air leak (0.704) and length of hospital stay (0.601) showed similar frequencies in both arms, although there was prolonged operating time (177.00 vs 117.88 min; $P<0.001$) and a smaller number of lymph nodes harvested (5.07 vs11.33, $P<0.001$) in the seg. arm. Of note, 3 patients in the seg. arm had persistent air leak and were handled with non-urgent intervention (6.52%). To exclude the interferences of age, gender and tumour size, propensity score matching (1:2) was used. As shown in Supplementary Material, Table S1, the seg. arm had longer operative times and smaller numbers of lymph nodes harvested compared to the lob. arm. With regards to blood loss, air leak and length of postoperative stay, no significant difference was observed between the groups. All these findings were consistent with unmatched analyses.

In the seg. arm, no relapses and no deaths were observed during the follow-up period through April 2021 (median: 3.4 years). No patient received adjuvant therapy.

DISCUSSION

Our initial experience showed how we dealt with difficult S^{10} nodules in a variety of settings. As we discussed previously, an S^{10} resection plus an adjuvant segment or a subsegment resection provided a wider margin, which allowed us to avoid having to compromise the oncological requirement. Similarly, a compromised margin was more likely to be happening in doing S^6 segmentectomy. Nakazawa *et al.* [20] emphasized that an S^6 segmentectomy might not always be as 'simple' as it seemed. In fact, some nodules located at the border of S^6 were not the best candidates for a so-called simple S^6 segmentectomy because it would compromise the surgical margin. This finding partially explained why survival outcomes differed in early-stage lung cancer, in which an S^6 resection showed worse survival outcomes than those of basal segment resections [21, 22].

A consensus on the definition of pulmonary intersegmental nodules has not been reached. In our centre, we have adopted the principle that if the virtual surgical margin at the 3D-CTBA, with the nodule as its centre, extends beyond the corresponding inter-SVs, the nodule is regarded as the intersegmental nodule [11]. Thus, being familiar with the relationship between the target nodule and the corresponding inter-SVs on 3D-CTBA images is helpful when designing a nodule-centred surgical resection range. Obviously, single segmentectomy is not a wise option in dealing with such intersegmental nodules. The sufficient margin (mean: 22.45 mm) obtained in the seg. arm was largely due to



Video 1: Thoracoscopic left $S^{10}+S^6$c segmentectomy via the inferior ligament approach. A 56-year-old man had a ground-glass nodule located deeply in the left lower lobe, measured at 1.0 cm on the computed tomography scan. The three-dimensional computed tomographic bronchography and angiography scan showed it was in S^{10} close to the V^6c (between S^6c and S^{10}). We performed an S^{10} plus S^6c resection with a satisfactory margin of 2.4 cm. Interestingly, the V^6c and V^{10}a emptied jointly into the common basal vein. After transection of the V^6c and V^{10}a, dissection was continued along the common basal vein and V^6a + b, respectively. The V^9b and V^{10}b were transected followed by V^9a2 (between S^{10}a and S^{10}b). The V^9a1 (between S^9a and S^{10}a) was well exposed to facilitate the recognition and transection of the target B^{10}. The A^{10} was subsequently recognized and transected. Afterwards, the B^6c and A^6c were handled in the same fashion using V^6a + b as the landmark. A modified inflation-deflation method was applied to identify the intersegmental planes between the target segment ($S^{10}+S^6$c) and the adjacent segments [19]. The placement of the staples was in line with the orientation of the intersegmental veins at the hilum. The inflated–deflated line was also used to guide the intersegmental plane dissection.

the preoperative inter-SVs guided surgical planning with 3D-CTBA.

Our previous study showed that even a sophisticated subsubsegmentectomy could be completed with the aid of 3D-CTBA [23]. However, as we stated previously, individualized S^{10} resection remains one of the most challenging procedures. It is currently recommended that the S^{10} resection be completed via the inferior pulmonary ligament approach because it maintains the continuity of S^6 and the residual basal segments and avoids dissection of the incomplete interlobar fissure [10]. With this approach, the target veins, bronchi and arteries can be isolated in sequence. Under the guidance of 3D-CTBA, the corresponding inter-SVs, which branch from the inferior pulmonary vein or the common basal vein, are initially recognized and preserved. However, identifying the target bronchi is challenging because it is located deeply in the hilum and cannot be easily accessed. Earlier studies reported a method to recognize the target segmental bronchi by using high-frequency jet ventilation combined with the 'slip-knot technique' [10]. However, other surgeons found it daunting to remove basal nodules using this operation [24]. It is often difficult to recognize each basal segmental and subsegmental bronchi under bronchoscopes. We found that the anatomical property of the inter-SVs of running between 2 adjacent bronchi at the hilum helps us to recognize the target bronchi and the preserved bronchi.

This strategy could potentially be extended to other segmentectomies. For instance, when a right S^1 segmentectomy is planned, V^1b (between S^1 and S^3) and V^2a (between S^1 and S^2) can be used as landmarks in B^1 recognition and intersegmental plane division. Left V^3b (between S^3 and S^4) should be carefully preserved in the left S^3 resection [25]. When a dissection is performed in a stem-to-branch fashion alongside the V^3b, the inferior boundary of B^3 is exposed, and the intersegmental plane between S^3 and S^4 is easily identified.

Table 1: Individualized S^{10} segmentectomy via the inferior pulmonary ligament approach

Laterality	Surgical procedures	*n*	%
Left	S^{10}	5	10.87
	$S^{10}+S^9$	17	36.96
	$S^{10}+S^6$c	1	2.17
Right	S^{10}	5	10.87
	$S^{10}+S^9$	15	32.61
	$S^{10}+S^*$	1	2.17
	$S^{10}+S^7$	2	4.35
Total		46	100.00

To date, limited studies have addressed the role of inter-SV in the efficacy and safety of a complex segmentectomy [7, 10]. Ramsay [14] showed that the inter-SV-guided dissection would mean a reduction of postoperative complications, because there should be fewer accidental invasions of the alveolar tissue. Our preliminary results were in accordance with his findings, showing that the air leaks that occurred in the seg. arm were comparable to those in the lob. arm. However, our data did not demonstrate a remarkable reduction in the incidence of postoperative air leaks in comparison with other studies (6.52% in this study vs 6.5% in Japan [26] and 7.0% in America [27]). This result could partially be interpreted by the relatively small sample size and the selection bias in this study.

In addition, patients who have a segmentectomy generally are less likely to have the same number of lymph nodes harvested as those who have a lobectomy. When we looked at the SEER database, we found that the median number of nodes harvested at a lobectomy and a segmentectomy for pT_1N_0 patients was 7 and 3, respectively [28]. Both Ding *et al.* [29] and Wolf *et al.* [30] reported similar findings. We routinely removed mediastinal lymph nodes as well as intrapulmonary nodes for analyses in segmentectomies.

To the best of our knowledge, this study represents the largest number of subjects reported regarding the surgical management of S^{10} nodules. Based on our initial experiences, we found this inter-SVs-guided method could have the following advantages:

Familiarizing surgeons with the relationship between inter-SVs and the nodules in 3D-CTBA helps design a nodule-centred surgical resection range with a safe margin.

The inter-SVs running between 2 adjacent bronchi at the hilum help the surgeon recognize the target bronchi and the adjacent preserved bronchi.

The inter-SVs peripherally extend into the intersegmental plane. Herein, the adequate exposure of the inter-SVs also helps guide the division of the intersegmental plane [17].

Limitations

This study has some limitations. First, our data potentially shed new light on dealing with difficult S^{10} nodules. However, the generalizability of our results is limited because we performed a retrospective single-institution study with limited numbers. Second, the oncological validity should be more carefully examined for early-stage lung cancer with a solid component. Lymphatic invasion and drainage are always major concerns with such nodules.

Table 2: Characteristics of patients with an individualized S10 segmentectomy and with a lower lobectomy for small nodules

Characteristics	Seg. arm (n = 46)	Lob. arm (n = 274)	P-Value
Age, mean ± SD	53.00 ± 11.10	59.66 ± 10.22	<0.001
Gender,[a] n (%)			0.989
Male	18 (39.13)	111 (40.51)	
Female	28 (60.87)	163 (59.49)	
Tumour size (mm), mean ± SD	10.13 ± 5.31	14.84 ± 4.01	<0.001
Operative time (min), mean ± SD	177.00 ± 39.67	117.88 ± 33.83	<0.001
Blood loss, mean ± SD	49.13 ± 41.89	45.98 ± 43.89	0.654
Surgical margin (mm), mean ± SD	22.45 ± 3.38	/	
Histological diagnosis,[b] n (%)			<0.001
Benign	5 (10.87)	14 (4.38)	
AIS	6 (13.04)	4 (1.46)	
MIA	11 (23.91)	12 (4.38)	
IAC	24 (52.17)	226 (82.48)	
SCC	0	10 (3.65)	
Others	0	8 (2.92)	
Lymph node count, mean ± SD	5.07 ± 3.47	11.33 ± 5.31	<0.001
Positive lymph node,[c] n (%)	0	15 (5.47)	0.212
Air leak (≥3 days),[c] n (%)	3 (6.52)	11 (4.01)	0.704
Length of postoperative stay, mean ± SD	4.96 ± 2.39	5.18 ± 2.76	0.601

[a]The χ^2 test was adopted.

[b]Fisher's exact test was used.

[c]The Yates-corrected χ^2 test was used. Age, tumour size, operative time, blood loss, surgery margin, examined lymph nodes and length of postoperative stay (days) were compared using the Student's t-test.

AIS: adenocarcinoma in situ; IAC: invasive adenocarcinoma; lob. arm: group having lower lobectomy for small nodules; MIA: minimally invasive adenocarcinoma; SCC: squamous cell carcinoma; SD: standard deviation; seg. arm: group having individualized S10 segmentectomy.

That was why we selected patients with GGO-predominate nodules for segmentectomy. On these occasions, inter-SVs were less likely to have lymphatic involvement [25]. In general, long-term follow-up and further studies are needed to validate the clinical benefit of this method.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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Conflict of interest: none declared.

Data Availability Statement

The data underlying this article cannot be shared publicly due to the privacy of the individuals who participated in the study. The data will be shared on reasonable request to the corresponding author.

Author contributions

Zhicheng He: Conceptualization; Funding acquisition; Methodology; Writing—original draft. **Xianglong Pan:** Data curation; Formal analysis; Methodology; Resources. **Zhihua Li:** Data curation; Investigation; Writing—original draft. **Qi Wang:** Data curation; Methodology; Writing—original draft. **Jun Wang:** Data curation; Resources; Supervision. **Wei Wen:** Data curation; Software; Supervision. **Quan Zhu:** Data curation; Formal analysis; Methodology. **Weibing Wu:** Funding acquisition; Resources; Supervision. **Liang Chen:** Conceptualization; Funding acquisition; Project administration; Resources; Writing—original draft.

Reviewer information

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