Original Article

Three-dimensional reconstruction for determining positional indications of pulmonary segmentectomy/subsegmentectomy for ground glass opacity-dominant clinical T1a-bN0 non-small cell lung cancer

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Background: The precision of segmentectomy/subsegmentectomy for ground glass opacity (GGO)-dominant cT1a-bN0 non-small cell lung cancer (NSCLC), including mono-segmentectomy, mono-subsegmentectomy, combined subsegmentectomies, and single segmentectomy with adjacent subsegmentectomy, has improved. The aim of this study is to investigate their positional indications by focusing on the three-dimensional location of lesions, utilizing three-dimensional computed tomography bronchography and angiography (3D-CTBA).

Methods: We retrospectively analyzed 195 patients with GGO-dominant cT1a-bN0 NSCLC who underwent segmentectomy/subsegmentectomy between August 2015 and November 2020. We included 173 patients: mono-segmentectomy (71, 41.04%), mono-subsegmentectomy (37, 21.39%), combined subsegmentectomies (42, 24.28%), and single segmentectomy with adjacent subsegmentectomy (23,13.29%). Patient demographics and perioperative outcomes were compared among groups to identify positional indications.

Results: Significant differences were observed among the four groups in terms of lobe location of the lesions and their relationships with adjacent intersegmental veins (P<0.001), but not in their diameter and depth (P=0.33; P=0.79). All groups showed similar surgical margins (P=0.77) despite differences in the number of subsegments resected (P<0.001). No perioperative deaths or postoperative recurrences were reported. For lesions located in the middle region, located inter-segmentally, or with a diameter >1 cm, a greater number of subsegments were resected (P=0.02; P<0.001; P=0.003), while the surgical margins were

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not inferior to those located in the outer region, located intra-segmentally, or with a diameter ≤1 cm (P=0.29; P=0.77; P=0.46).

Conclusions: It is the specific lobe in which lesions are located and their relationship with adjacent intersegmental veins that determine the specific surgical procedure of segmentectomy/subsegmentectomy for GGO-dominant cT1a-bN0 NSCLC, rather than their diameter and depth.

Keywords: Segmentectomy; subsegmentectomy; positional indication; surgical margin

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Introduction

Lung cancer continues to be the most commonly identified cancer globally and the primary cause of cancer-related deaths (1). The increased use of low-dose computed tomography (LDCT) has significantly boosted the identification of early non-small cell lung cancer (NSCLC) (2,3). Findings from the JCOG0802, CALGB140503, and other randomized controlled trials have strongly advocated for sublobectomy in treating early-stage NSCLC with tumors under 2 cm in diameter (4-8).

Segmentectomy and subsegmentectomy, surgical procedures that conserve more lung tissue while offering results comparable to lobectomy, have gained widespread acceptance for managing peripheral ground glass opacity (GGO)-dominant cT1a-bN0 NSCLC (9,10). In clinical practice, it has been observed that these procedures can be further categorized into mono-segmentectomy, mono-subsegmentectomy, combined subsegmentectomies, and single segmentectomy with adjacent subsegmentectomy. These subdivisions allow for more precise surgical interventions tailored to the specific characteristics and locations of lung nodules.

The National Comprehensive Cancer Network (NCCN) guidelines recommend intentional segmentectomy for GGO-dominant cT1a-bN0 NSCLC located in the periphery of the lung parenchyma (11). In a research comparing outcomes of sublobar resection with lobectomy, peripheral pulmonary nodules were defined as nodules of which its centers are located on the periphery in the coronal, sagittal, and axial computed tomography (CT) images (12). Regrettably, the positional indication is generally described as a "peripheral lesion", yet the indications of more precise surgical procedures, particularly those related to location, remain underexplored.

Due to the characteristic trajectory of intersegmental veins along the intersegmental planes, we classify lesions as either intra-segmental or inter-segmental using three-dimensional computed tomography bronchography and angiography (3D-CTBA) (13). We also employ our center's depth ratio measurement method to quantify the depth of lesions within the lung field using 3D-CTBA (14). By integrating these assessments with traditional indications, we aim to explore surgical indications for the more precise

Highlight box

Key findings

- It is the specific lobe in which lesions are located and their relationship with adjacent intersegmental veins that determine the specific surgical procedure of segmentectomy/subsegmentectomy for ground glass opacity (GGO)-dominant cT1a-bN0 non-small cell lung cancer (NSCLC), rather than their diameter and depth.

What is known and what is new?

- The precision of segmentectomy and subsegmentectomy for GGO-dominant cT1a-bN0 NSCLC, which includes mono-segmentectomy, mono-subsegmentectomy, combined subsegmentectomies, and single segmentectomy with adjacent subsegmentectomy, has improved. However, the selection criteria for these surgical techniques, particularly the positional indications, have not been adequately explored.
- This study investigates the positional indications for segmentectomy and subsegmentectomy in GGO-dominant cT1a-bN0 NSCLC. We find that the specific surgical procedure is determined not by the diameter or depth of the lesions but by their location within a specific lobe and their proximity to adjacent intersegmental veins. This insight refines the selection process for the most appropriate surgical procedure based on anatomical details rather than size criteria alone.

What is the implication, and what should change now?

- When determining the surgical strategy for segmentectomy/subsegmentectomy, it is crucial to emphasize assessing specific positional indications, including the lobe location of the lesions and their relationships with adjacent intersegmental veins.

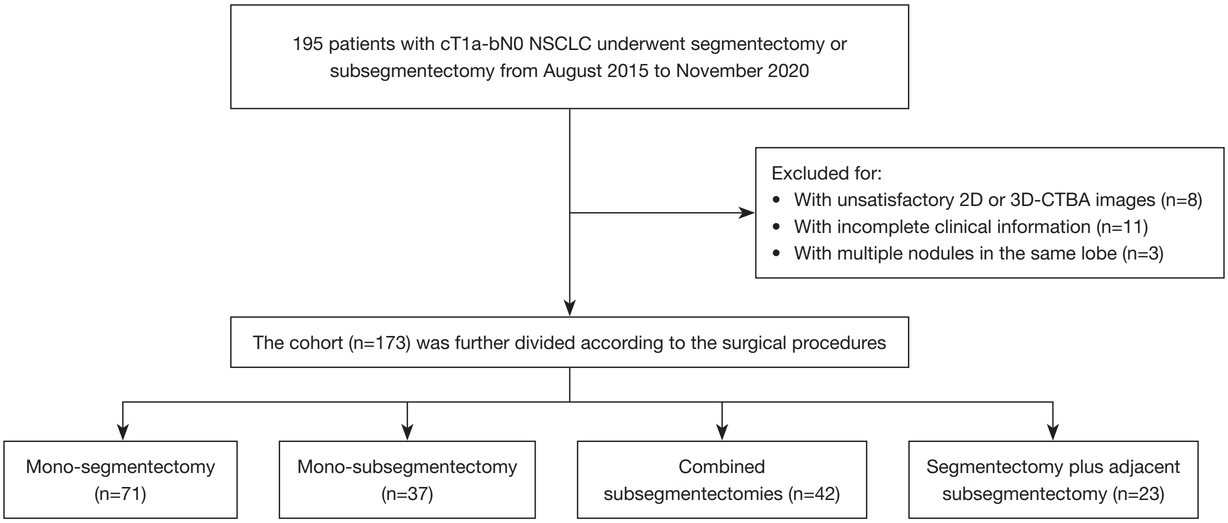

Figure 1 Flow chart of patient selection. NSCLC, non-small cell lung cancer; CTBA, computed tomography bronchography and angiography.

segmentectomy and subsegmentectomy. We present this article in accordance with the STROBE reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-24-595/rc).

Methods

Study cohort

This research was carried out in accordance with the revised 2013 Declaration of Helsinki and was approved by the Ethics Review Boards of Jiangsu Province Hospital and The First Affiliated Hospital of Nanjing Medical University, under approval number 2019-SR-450. For this retrospective analysis, the requirement for consent was waived.

We retrospectively analyzed the clinical data of patients with GGO-dominant cT1a-bN0 NSCLC who underwent segmentectomy or subsegmentectomy from August 2015 to November 2020 at Jiangsu Province Hospital and The First Affiliated Hospital of Nanjing Medical University (*Figure 1*).

Inclusion criteria were as follows: (I) possession of complete DICOM data of chest CT before hospitalization; (II) diagnosis of cT1a-bN0 NSCLC with a GGO component >50%; (III) undergoing segmentectomy or subsegmentectomy through video-assisted thoracic surgery (VATS).

Exclusion criteria were as follows: (I) patients with unsatisfactory 2D or 3D-CTBA imaging; (II) patients with incomplete clinical information (such as surgical margin); (III) patients with multiple lesions in the same lobe.

Perioperative preparations and intraoperative procedures

Firstly, the patient's preoperative thin-section CT images (taken within 1 month) were transferred to the 3D reconstruction workstation (DeepInsight, Demo Version 21.0). A 3D-CTBA with a simulated surgical margin sphere (≥2 cm) was set up according to the specified process (*Figure 2*).

Secondly, two senior thoracic surgeons review the CT and 3D-CTBA images for each patient and then collaboratively planned the specific surgical procedures. In principle, all preoperatively planned segmentectomies are designed to ensure a surgical margin—the minimum distance from the lesion to the approximate intersegmental boundaries as suggested by the segmental veins—of at least 2 cm. This standard serves as a baseline to maximize the likelihood that the actual distance to the irregular intersegmental boundaries is at least as great as the maximum diameter of the cT1a-b lesion, accounting for the uneven nature of these boundaries. The depth position of the lesion, defined as the distance to the hilum, was evaluated using the depth ratio method based on three symmetric sectors (14) (*Figure 2*). The major scenarios of the lesion's relationship with the adjacent intersegmental veins are as follows: (I) if a lesion and its 2 cm surgical margin sphere are located within one subsegment, a mono-subsegmentectomy will be performed (*Figure 3A*); (II) if a lesion and its surgical margin sphere span more than one subsegment but remain within one segment, an intra-segmental combined subsegmentectomies (not involving

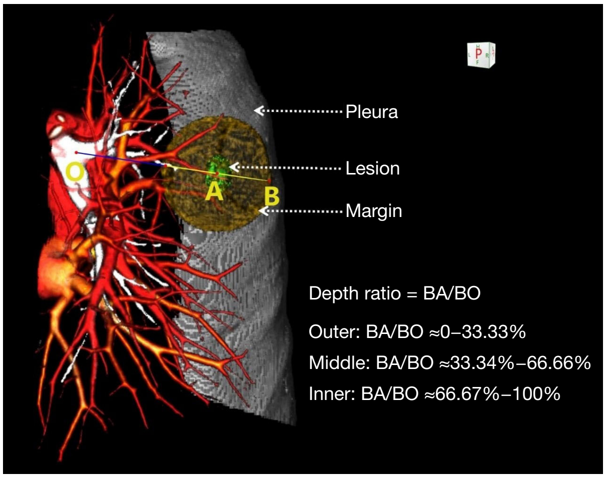

Figure 2 Measurement of the depth ratio in a 3D-CTBA image. The center of the bronchial opening of the pulmonary lobe to which the lung nodule belongs is marked as point O, and the center of the pulmonary nodule is labeled as point A. Extend the line connecting points O and A towards the visceral pleura. The extension that intersects the rib-facing visceral pleura or the well-developed interlobar pleural membrane is marked as point B. The depth of the pulmonary nodule from the hilum is approximately represented by the ratio BA/BO. Nodules with a depth ratio of 0–33.3%, 33.4–66.6%, and 66.7–100% are defined as outer region, middle region, and inner region nodules, respectively. CTBA, computed tomography bronchography and angiography.

all subsegments of this segment) or mono-segmentectomy (involving all subsegments of this segment) will be performed (*Figure 3B*); (III) if a lesion and its surgical margin sphere involve more than one segment but not all subsegments of the relative segment, an inter-segmental combined subsegmentectomies (*Figure 3C*) or single segmentectomy plus an adjacent subsegmentectomy will be performed (*Figure 3D*), respectively.

Thirdly, the actual anatomy is continuously verified with 3D-CTBA images as the surgery progresses. This allows the extent of surgical resection to be standardized further, ensuring a precise match between the preoperative plan and the intraoperative resection. After the complete excision of the target area, the surgical margin distance is measured. This distance is defined as the shortest vertical distance from the outer edge of the tumor to the stapler edge, as observed with the naked eye, and is immediately sent for rapid frozen pathology.

Finally, to monitor long-term postoperative outcomes, we instituted a structured follow-up protocol. Patients were scheduled for follow-up visits at 3, 6, and 12 months after surgery, and then biannually thereafter. At each visit, a CT scan of the chest was conducted to assess for any signs of recurrence at the surgical margins and to ensure local control. Additionally, a final telephone follow-up was conducted in June 2024 to confirm the absence of

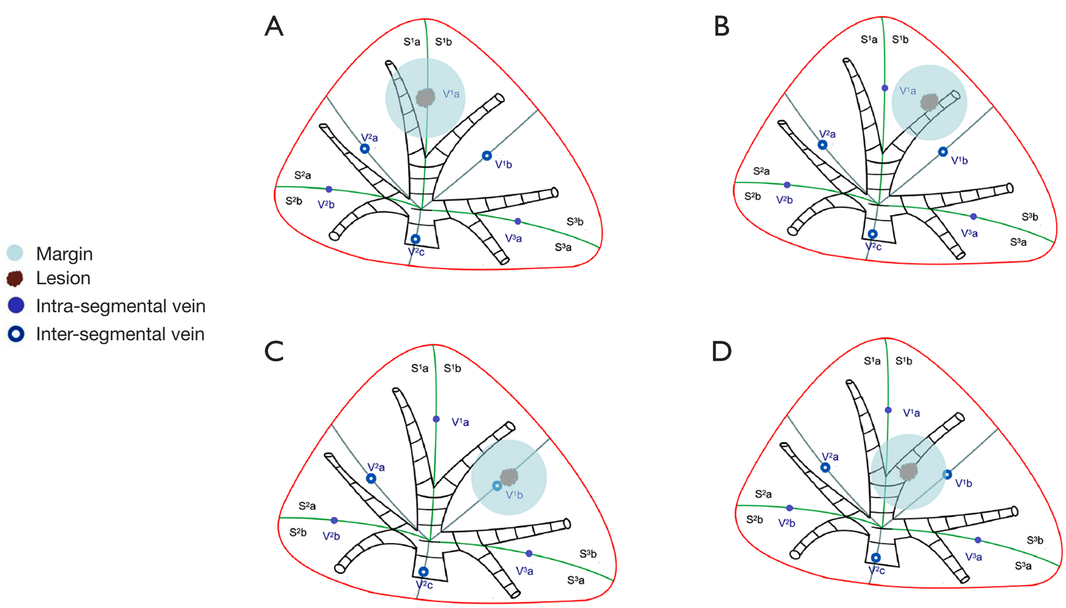

Figure 3 Schematic diagram of lesions treated with various surgical procedures: mono-segmentectomy (A), mono-subsegmentectomy (B), combined subsegmentectomies (C), and single segmentectomy with an adjacent subsegmentectomy (D).

recurrence, with follow-up periods ranging from 3.5 to nearly 9 years for patients initially treated between August 2015 and November 2020.

Statistical analysis

Continuous variables were presented using the median and interquartile range (IQR) for non-normal distributions, and the mean ± standard deviation (SD) for normal distributions. We used the Mann-Whitney *U* test and Kruskal-Wallis H test to analyze non-normal distributions, and the Student's *t*-test and one-way ANOVA for normal distributions. For categorical variables, the Chi-squared test or Fisher's exact test was applied, with results expressed as number (%). Statistical significance was set at P<0.05 (two-sided). All statistical analyses were performed using SPSS (IBM SPSS Statistics, version 26.0).

Results

Patients and clinical characteristics of the study cohort

A total of 173 patients were ultimately included in the study (*Figure 1*). Details of the demographic and clinical characteristics are presented in *Table 1*, while the exact surgical procedure information is detailed in Table S1.

Univariate analysis revealed no statistically significant differences between the four groups regarding demographic and clinical data such as age (P=0.59), sex (P=0.35), smoking history (P=0.35), comorbidities (including pulmonary and cardiac) (P=0.65).

In order to determine which factors influence the specific surgical procedure of segmentectomy/subsegmentectomy for GGO-dominant cT1a-bN0 NSCLC, we examined potential differences among four groups. Our analysis revealed no statistically significant differences between the groups regarding tumor size (P=0.33, 0.63) and depth location (P=0.79). However, the lobe location of lesions and their proximity to adjacent intersegmental veins were significantly associated with the choice of surgical procedures (P<0.001). Specifically, lesions situated in the left upper lobe are more likely to undergo combined subsegmentectomies, whereas lesions treated with mono-segmentectomy or mono-subsegmentectomy are predominantly located intra-segmentally. Conversely, lesions requiring single segmentectomy plus adjacent subsegmentectomy are typically inter-segmentally located. Therefore, it is the positional indicators, identified as the specific lobe in which lesions are located and their relationship with adjacent intersegmental veins, that determine the specific surgical procedure, rather than their diameter and depth.

Postoperative clinical data

To explore the comparative postoperative outcomes of different surgical procedures for GGO-dominant cT1a-bN0 NSCLC, we conducted comparisons across four groups. Univariate analysis indicated no statistically significant differences among the four groups in terms of operative and pathological characteristics, including operation time (P=0.18), histologic type (P=0.64), surgical margin (P=0.77), postoperative air leakage (P=0.93), drainage volume (P=0.33), time of drainage (P=0.27), and hospitalization duration (P=0.56). Pathological examination revealed no lymph node metastasis. There were no perioperative deaths or postoperative recurrences by the end of this study (*Table 2*). These findings suggest that all four surgical techniques are comparably safe and reliable.

The number of resected subsegments was the only surgical outcome that showed significant variation among the four groups (P<0.001). Specifically, single segmentectomy plus adjacent subsegmentectomy resulted in the highest number of subsegments resected, whereas mono-subsegmentectomy involved the fewest. The number of subsegments resected in mono-segmentectomy depended on the targeted pulmonary segments. Among the 71 mono-segmentectomies performed, 38 involved resecting three subsegments, including 16 RS^6 resections, 12 LS^6 resections, 7 LS^{1+2} resections, and 3 LS^3 resections. The other mono-segmentectomies typically involved resecting two subsegments (detailed information available in Table S1). For the 42 combined subsegmentectomies, most cases involved resecting two subsegments. Of these, only four—all located in the upper left lung—included the resection of three subsegments: two $S^{1+2}a+S^3(b+c)$ resections, one $S^{1+2}(a+b)+S^3c$ resection, and one $S^3(a+b)+S^4b$ resection.

Subanalysis of the surgical margin and resected subsegments number

Finally, an exploratory analysis was conducted to identify factors influencing surgical margins and the number of resected subsegments. Special attention was given to the classical surgical indications such as lesion diameter, as well as locational indicators proposed in this study, including

Table 1 The demographic and clinical characteristics by surgical procedures

Variables	Total (n=173)	Surgical procedures				P
		Mono-segmentectomy (n=71)	Mono-subsegmentectomy (n=37)	Combined subsegmentectomies (n=42)	Single segmentectomy plus adjacent subsegmentectomy (n=23)	
Age, years	54 [45, 63]	53 [44, 60]	54 [48, 63]	54 [40, 64]	54 [47, 64]	0.59
Sex						0.35
Male	56 (32.37)	22 (30.99)	16 (43.24)	13 (30.95)	5 (21.74)	
Female	117 (67.63)	49 (69.01)	21 (56.76)	29 (69.05)	18 (78.26)	
Smoking history						0.35
Ever	14 (8.09)	9 (12.68)	1 (2.70)	3 (7.14)	1 (4.35)	
Never	159 (91.91)	62 (87.32)	36 (97.30)	39 (92.86)	22 (95.65)	
Comorbidity						0.65
Never	145 (83.82)	62 (87.32)	29 (78.38)	35 (83.33)	19 (82.61)	
Ever	28 (16.18)	9 (12.68)	8 (21.62)	7 (16.67)	4 (17.39)	
Tumor size, cm	1.19 [0.95, 1.47]	1.20 [0.97, 1.56]	1.13 [0.89, 1.40]	1.14 [0.93, 1.41]	1.35 [1.00, 1.63]	0.33
Tumor size						0.63
≤1 cm	53 (30.64)	19 (26.76)	14 (37.84)	14 (33.33)	6 (26.09)	
>1 cm	120 (69.36)	52 (73.24)	23 (62.16)	28 (66.67)	17 (73.91)	
Lobe location						<0.001
Right upper lobe	57 (32.95)	25 (35.21)	16 (43.25)	5 (11.91)	11 (47.83)	
Right lower lobe	35 (20.23)	20 (28.17)	5 (13.51)	3 (7.14)	7 (30.43)	
Left upper lobe	55 (31.79)	10 (14.08)	11 (29.73)	31 (73.81)	3 (13.04)	
Left lower lobe	26 (15.03)	16 (22.54)	5 (13.51)	3 (7.14)	2 (8.70)	
Transverse location						<0.001
Intra-segmental nodule	124 (71.68)	71 (100.00)	37 (100.00)	16 (38.10)	0	
Inter-segmental nodule	49 (28.32)	0	0	26 (61.90)	23 (100.00)	
Depth location						0.79
Inner	0	0	0	0	0	
Middle	38 (21.97)	16 (22.54)	6 (16.22)	10 (23.81)	6 (26.09)	
Outer	135 (78.03)	55 (77.46)	31 (83.78)	32 (76.19)	17 (73.91)	

Data are presented as median [interquartile range] or n (%). Comorbidity includes pulmonary and cardiac comorbidities.

the longitudinal position—lesion depth, and the transverse position—lesion's relationship with adjacent intersegmental veins.

Our findings, detailed in *Table 3*, showed that lesions located in the middle region (P=0.02), inter-segmentally (P<0.001), or with a diameter greater than 1 cm (P=0.003) necessitated a greater number of resected subsegments. Despite this, the surgical margins for these lesions were comparable to those located in the outer region (P=0.29), intra-segmentally (P=0.77), or with a diameter of 1 cm or less (P=0.46).

This comprehensive analysis highlights how lesion

Table 2 The operative and pathologic characteristics by procedures

Variables	Total (n=173)	Surgical procedures				P
		Mono-segmentectomy (n=71)	Mono-subsegmentectomy (n=37)	Combined subsegmentectomies (n=42)	Single segmentectomy plus adjacent subsegmentectomy (n=23)	
Operation time, min	160 [135, 193]	160 [130, 190]	150 [133, 182]	165 [140, 199]	165 [150, 210]	0.18
Histology						0.64
AAH	4 (2.31)	1 (1.41)	2 (5.41)	1 (2.38)	0	
AIS	20 (11.56)	6 (8.45)	6 (16.22)	4 (9.52)	4 (17.39)	
MIA	78 (45.09)	34 (47.89)	16 (43.23)	20 (47.63)	8 (34.78)	
IAC	64 (36.99)	28 (39.43)	13 (35.14)	14 (33.33)	9(39.13)	
Other	7 (4.05)	2 (2.82)	0	3 (7.14)	2 (8.70)	
Pathologic nodal status						>0.99
N0	173 (100.00)	71 (100.00)	37 (100.00)	42 (100.00)	23 (100.00)	
N1/2	0	0	0	0	0	
Surgical margin						0.77
<2 cm	14 (8.09)	5 (7.04)	3 (8.11)	5 (11.90)	1 (4.35)	
≥2 cm	159 (91.91)	66 (92.96)	34 (91.89)	37 (88.10)	22 (95.65)	
Resected subsegments						<0.001
1–2	107 (61.85)	33 (46.48)	37 (100.00)	37 (88.10)	0 (0)	
3–5	66 (38.15)	38 (53.52)	0	5 (11.90)	23 (100.00)	
Air leakage						0.93
Yes	18 (10.40)	8 (11.27)	3 (8.11)	4 (9.52)	3 (13.04)	
No	155 (89.60)	63 (88.73)	34 (91.89)	38 (90.48)	20 (86.96)	
Drainage volume, mL	417 [295, 602]	400 [300, 625]	390 [295, 550]	400 [295, 510]	550 [280, 790]	0.33
Time of drainage, day	2.25 [2, 3]	2 [2, 3]	2 [2, 3]	2.5 [2, 3]	3 [2, 4]	0.27
Hospitalization time, day	4 [3.4, 5.2]	4 [4, 5]	4 [3, 5]	4 [3, 6]	4 [3, 5]	0.56
Recurrence						>0.99
Yes	0	0	0	0	0	
No	173 (100.00)	71 (100.00)	37 (100.00)	42 (100.00)	23 (100.00)	

Data are presented as median [interquartile range] or n (%). AAH, atypical adenomatous hyperplasia; AIS, adenocarcinoma in situ; MIA, minimally invasive adenocarcinoma; IAC, invasive adenocarcinoma.

size, depth, and precise anatomical positioning relative to intersegmental veins are critical in determining the number of subsegments resected. Despite these factors influencing the extent of the resection, they do not compromise the quality of surgical margins achieved.

Discussion

The widespread application of chest LDCT in health screenings among Chinese populations has led to the increased identification of early-stage lung cancers, predominantly

Table 3 The surgical margin and resected subsegments affected by tumor size and other positional indications

Variables	Depth location			Transverse location			Tumor size		
	Middle region (n=38)	Outer region (n=135)	P	Intra-segmental (n=124)	Inter-segmental (n=49)	P	≤1 cm (n=53)	>1 cm (n=120)	P
Surgical margin, n (%)			0.29			0.77			0.46
<2 cm	1 (2.63)	13 (9.63)		11 (8.87)	3 (6.12)		6 (11.32)	8 (6.67)	
≥2 cm	37 (97.37)	122 (90.37)		113 (91.13)	46 (93.88)		47 (88.68)	112 (93.33)	
Resected subsegments, n (%)			0.02			<0.001			0.003
1–2	17 (44.74)	90 (66.67)		97 (78.23)	10 (20.41)		42 (79.25)	65 (54.17)	
3–5	21 (55.26)	45 (33.33)		27 (21.77)	39 (79.59)		11 (20.75)	55 (45.83)	
Tumor size, n (%)			0.02			0.58			–
≤1 cm	18 (47.37)	35 (25.93)		40 (32.26)	13 (26.53)		–	–	
>1 cm	20 (52.63)	100 (74.07)		84 (67.74)	36 (73.47)		–	–	
Transverse location, n (%)			0.19			–			–
Intra-segmental	24 (63.16)	100 (74.07)		–	–		–	–	
Inter-segmental	14 (36.84)	35 (25.93)		–	–		–	–	

affecting a younger demographic (15). Many of these detected nodules are NSCLC lesions that are smaller than 2 cm and are characterized as GGO-dominant. Numerous studies have focused on the role of segmentectomy in the surgical management of GGO-dominant clinical T1a-bN0 NSCLC, acknowledging its potential efficacy (4-8). As surgical techniques advance towards increased precision, procedures targeting pulmonary segments or subsegments as the minimal anatomical units have been developed. These include methods such as subsegmentectomy, which involve reduced resection extents, and strategies such as combined subsegmentectomies and single segmentectomy with adjacent subsegmentectomy, designed to balance adequate surgical margins with minimal resection extent. Currently, research on these surgical procedures primarily focuses on technical descriptions, with scant reports on their selection criteria (how to choose among various segmentectomy or subsegmentectomy procedures) and outcomes including margins, pathology, and recurrence rates (16). In our study, we classified 173 cases into four groups based on the surgical procedures, revealing that the lobe location of the lesions and their relationships with adjacent intersegmental veins influence the choice of surgical procedures. The intersegmental veins, serving as natural planes between pulmonary segments, suggest that intra-segmental nodules are more likely to undergo mono-segmentectomy or mono-subsegmentectomy, resulting in fewer resected subsegments. Conversely, inter-segmental nodules are more likely to require single segmentectomy plus adjacent subsegmentectomy, leading to a greater number of resected subsegments. Lesions in the upper left lung are more likely to undergo combined subsegmentectomies, correlating with the anatomical complexity where segments S^{1+2} and S^3 each consists of three subsegments.

The evolution of surgical procedures reflects concerted efforts to optimize oncological outcomes while preserving respiratory units with full functionality. Detailed studies on pulmonary function following sublobar resections have indicated that the preservation of pulmonary function may correlate with the number of subsegments resected. For instance, Nomori *et al.* suggested that surgical interventions should involve ≤2 lung segments or ≤5 lung subsegments (17), while Chen *et al.* proposed that the number of resected subsegments should not exceed half of the total number of subsegments in any lung lobe (18). Consequently, our center has adopted the principle of targeting the lesion focus and considering the pulmonary subsegment as the anatomical unit, which has guided the completion of numerous surgeries and the initiation of this study (19). In our dataset, the 173 pulmonary nodules analyzed included surgeries on 37 cases involving 1 subsegment, 70 cases involving 2 subsegments, 59 cases involving 3 subsegments, 5 cases involving 4 subsegments, and 2 cases involving 5 subsegments. The maximum number of subsegments resected was 5, equivalent to half of the total subsegments in the left upper lobe, with surgical procedures such as LS^{1+2}(a+b)+S^3, aligning with the guidelines suggested by Nomori's team and Chen's team for limiting the number of subsegment resections.

We also focused on an important surgical outcome, the surgical margin, which exhibited variations across the four groups in our study. Surgical margins are critically linked to therapeutic efficacy and prognosis. However, achieving satisfactory margins in segmentectomy is not always possible, as indicated by previous literature (20). In our cohort, the majority of cases achieved margins of ≥2 cm (91.91%, 159/173). There were 14 cases where the margin exceeded the largest tumor diameter but was less than 2 cm, and no cases exhibited margins less than the largest tumor diameter. Furthermore, there were no initial recurrences reported during the study period. This may be attributed to our center's use of preoperative 3D-CTBA for planning the surgical procedure, enabling the resection of additional subsegments or a lobectomy when necessary, particularly for nodules located close to intersegmental veins or deeper, thus ensuring adequate margins.

In this study, we utilized the depth ratio measurement method proposed by our center to quantify the extent of lesion distribution within the pulmonary parenchyma (14), which serves as a supplement to the "peripheral parenchyma" concept outlined in the NCCN guidelines (11). As the pulmonary segments and subsegments approach the hilum, the parenchyma decreases, posing greater challenges in meeting surgical margin requirements; similarly, larger diameters make it difficult to achieve adequate surgical margins in single subsegment resections. Contrary to our initial hypothesis, variations in depth and lesion size did not significantly impact the surgical margins. Initially, our research team hypothesized that as nodules were located deeper (closer to the hilum), the difficulty of achieving a 2 cm margin would increase. Beyond a certain depth threshold, sublobar resection would not be feasible even with minimal margin standards. However, our analysis revealed that most margins met or even exceeded 2 cm, predominantly in the middle region, suggesting that the scope of segmentectomy should not be confined to the outer third of the pulmonary parenchyma. With proper surgical planning, lesions located in the middle third can still be effectively managed through precise segmentectomy/subsegmentectomy. Cases where preoperative planning reveals an inability to ensure adequate margins are referred for lobectomy.

There are several limitations that warrant mentioning in this study. Firstly, its retrospective nature unfortunately led to the absence of specific preoperative and postoperative pulmonary function data, which could have further corroborated the outcomes associated with the reduction in the number of lung segments. Secondly, the analysis was exploratory and based on data from a single center. To enhance the robustness and generalizability of our findings, future research must include multicenter studies to expand the sample size.

Conclusions

In summary, our findings indicate that for GGO-dominant cT1a-bN0 NSCLC, it is the specific lobe in which lesions are located and their relationship with adjacent intersegmental veins that determine the specific surgical procedure of segmentectomy/subsegmentectomy, rather than their diameter and depth. Lesions in the left upper lobe frequently require combined subsegmentectomies, while the necessity for mono-segmentectomy or combined segmentectomy with adjacent subsegmentectomy depends on whether lesions are intra-segmentally or inter-segmentally located.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-24-595/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-24-595/coif). The authors have no conflicts of interest to declare.

Ethical Statement: 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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Jiangsu Province Hospital and The First Affiliated Hospital of Nanjing Medical University Ethics Review Board (No. 2019-SR-450). Individual consent for this retrospective analysis was waived.

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