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Observation of bronchial anatomy and variation of the middle lobe of the right lung based on three-dimensional reconstruction of lung CT

Bin Zhao[1,2†], Wenbo Wu[1†] and Guochen Duan[1,3*]

Abstract

Purpose To explore the anatomical types and variations of lung segments and subsegment bronchi based on CT 3D reconstruction technology, and to provide anatomical theoretical support for thoracic surgeons in terms of surgical techniques.

Methods The 3D CT reconstructed images of 541 patients were retrospectively analyzed. We explored the anatomical structure of the bronchi in the middle lobe of the right lung, sorted out the variations, and classified them in detail according to different bronchial types.

Results In the CT 3D reconstruction of 541 patients, the bronchial anatomical types of the right middle lobe were divided into two types. There were 530 cases (98.0%) of two-branched type and 11 cases (2.0%) of three-branched type, and no four-branched type was found in the data of this paper. In addition, the spatial relationship between B_4 and B_5, and the spatial relationship between subsegmental bronchi B_{4a}, B_{4b}, B_{5a}, and B_{5b} are analyzed. The most common anatomical type and spatial relationship of the right middle lobe bronchi in the two-branched type were B_4 and B_5 in the external-internal relationship, B_{4a} and B_{4b} in the external-internal relationship, and B_{5a} and B_{5b} in the upper and lower relationship, and this subtype was 416 cases (76.9%). In addition, 23 cases (3.9%) were found to have a spatial relationship between B_4 and B_5 in the right middle lobe similar to the lingual bronchial subtype in the left upper lobe.

Conclusion We used a large number of CT 3D reconstructed images to explore the anatomical types and variations of the bronchi in the middle lobe of the right lung. Thoracic surgeons can use our data to guide increasingly delicate lobectomy and segmentectomy.

Keywords Lung anatomy, Three-dimensional CT, Right middle lobe bronchi, Lung cancer surgery, Segmentectomy

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Introduction

Lung cancer has become the most common malignant tumor in the world [1]. With the early diagnosis and early screening of lung malignant tumors and the increasing sophistication of thoracic surgery, lung segmentectomy has become the most important emerging surgical method due to its small damage and the prognosis of lobectomy, and the number of patients who need to undergo lung segmentectomy is increasing [2–4]. Segmentectomy requires accurate intraoperative identification and identification of the bronchi at the level of lung segments and subsegments, which undoubtedly poses new challenges to thoracic surgeons [5]. In today's challenging world, CT 3D reconstruction technology is developing rapidly, which can provide thoracic surgeons with a new way to intuitively identify the passage of bronchi, arteries and veins at all levels, and can provide strong technical support for more delicate surgical methods [6–8]. Exploring the anatomical types and variations of the pulmonary segment bronchi and subsegment bronchi can provide an important imaging reference for thoracic surgeons. However, there are not a large number of relevant articles to clearly explain such a detailed anatomical structure and variation of the bronchi in the middle lobe of the right lung, and the purpose of this article is to clearly point out the route and variation types of the bronchi in the middle lobe of the right lung, so as to provide important guidance for pulmonary segment surgery in thoracic surgery.

Patients and methods

Patient preparation and examination

This is a retrospective study that included the imaging data of 541 patients who underwent thin-slice CT examination in the Department of Thoracic Surgery of Hebei General Hospital from October 2020 to October 2022. Among them, there were 249 males and 292 females, with an average age of 56 years. All procedures for the human participants involved in this study are consistent with the Declaration of Helsinki (revised 2013). The Research Ethics Committee of Hebei General Hospital approved this retrospective study (No. 2024-LW-070). Because this study is retrospective, it is without the consent of the patient. Bronchial changes in the middle lobe of the right lung were classified and summarized.

Table 1 Anatomical types and proportions of bronchus in the right middle lobe of the 541 patients

Bronchial branch type of the right middle lobe	NO.	%
Two-branched type		
B_4,B_5	508	93.9
B_{4a}, $B_{4b}+B_5$	18	3.3
B_{5b}, $B_{5a}+B_4$	3	0.6
B_{5a}, $B_{5b}+B_4$	1	0.2
Three-branched type		
B_{4a}、B_{4b}、B_{5a+5b}	5	0.9
B_{4a}、B_{5a}、B_{4b+5b}	5	0.9
B_{5a}、B_{5b}、B_{4a+4b}	1	0.2

Reconstruction of 3D-CTAB imaging

The bronchial CT images of the patient were scanned by a 128-slice CT machine from Siemens Definition Flash (Siemens AG, Germany). Scanning parameters: tube voltage 120 kV, tube current 200 ~ 300 mA, scanning layer thickness 2 mm, layer spacing 1 mm. The obtained data was transferred to 3D reconstruction software (Infer Operate Thorax Planning), which was used to convert the data into a 3D structural bronchial model. The 3D reconstruction was completed and verified by at least two thoracic surgeons, and the accuracy of the reconstruction was confirmed by mutual validation with the 2D CT images.

Definition of arterial vessels in the middle lobe of the right lung (RML)

We use the same nomenclature to describe the segmental structure based on the study by Boyden et al. [9, 10]B_X is the location of the normal lung segment or subsegment from the adjacent lung segment or subsegment bronchi, the specific lung segment bronchi is indicated by Arabic numerals on the corresponding letters, and the subsegment bronchi is named with lowercase English letters. The middle lobe of the right lung is mainly segmented by the bronchial shape of the middle lobe of the right lung, and its shape variation is relatively small, and the bronchi of each segment joins the middle lobe bronchus and finally joins the right main bronchus.

Statistics

All statistical analyses were performed using SPSS 26.0 (SPSS, Chicago, IL, USA). Non-normally distributed continuous variables are described in terms of mean, and count data are described in terms of frequency and percentage.

Results

Among the 541 patients in this study, there were two types of bronchi in the right middle lobe (Table 1):1. There were 530 cases (98.0%) of bibranched type, of which 508 cases (93.9%) were normal B_4 and B_5 types, and the rest were $B_{4b}+B_5$ co-trunk cases (3.3%) (Fig. 1),3 cases (0.6%) of $B_{5a}+B_4$ co-trunk (Fig. 2) and $B_{5b}+B_4$ co-trunk in 1 case (0.2%) (Fig. 3).No $B_{4a}+B_5$ co-trunk was found in this study.2. There were 11 cases (2.0%) of the three-branched type, which were B_{4a}, B_{4b}, $B_{5a}+B_{5b}$ 5 (0.9%) (Fig. 4), B_{4a}, B_{5a}, $B_{4b}+B_{5b}$ 5 (0.9%) (Fig. 5) and B_{5a}, B_{5b}, $B_{4a}+B_{4b}$ 1 (0.2%) (Fig. 6), but there were no three-branched types of B_{4b}, B_{5b}, $B_{4a}+B_{5a}$.No four-branched

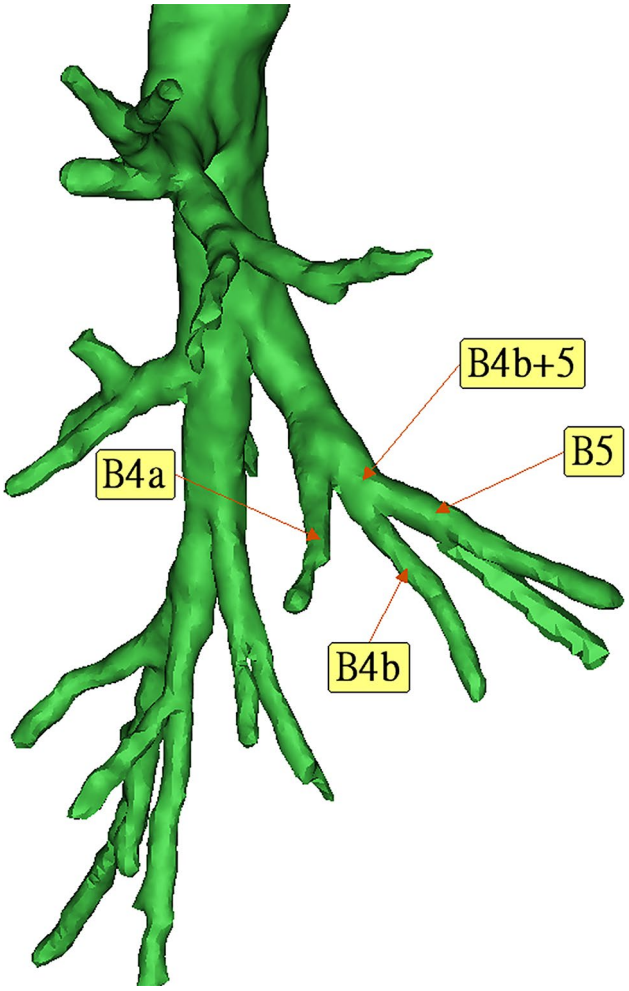

Fig. 1 3D model of the B_{4b}+B_5 cotrunk of the middle lobe of the right lung

type is found in the data in this article. The results of these studies are similar to those of previous studies, suggesting that the middle lobe bronchus of the right lung are more common in a bibranched type.

In addition, the spatial relationship between B_4 and B_5, and the spatial relationship between subsegmental bronchi B_{4a} and B_{4b} and B_{5a} and B_{5b} were also analyzed, among which the most common anatomical type and spatial relationship of the right middle lobe bronchi in the two branched types were B_4 and B_5 in the external and internal relationship, B_{4a} and B_{4b} in the external and internal relationship, and B_{5a} and B_{5b} in the upper and lower relationship, and this subtype was 416 cases (76.9%) (Fig. 7). In addition, there were the following subtypes of B_4 and B_5 external and internal relationship: 1. B_{4a} and B_{4b} showed an up-down relationship, and B_{5a} and B_{5b} showed an up-down relationship in 8 cases (1.5%) (Fig. 8); B_{4a} and B_{4b} were externally and internally related, and B_{5a} and B_{5b} were externally and internally related in 8 cases (Fig. 9);3. B_{4a} and B_{4b} showed an up-down relationship, and B_{5a} and

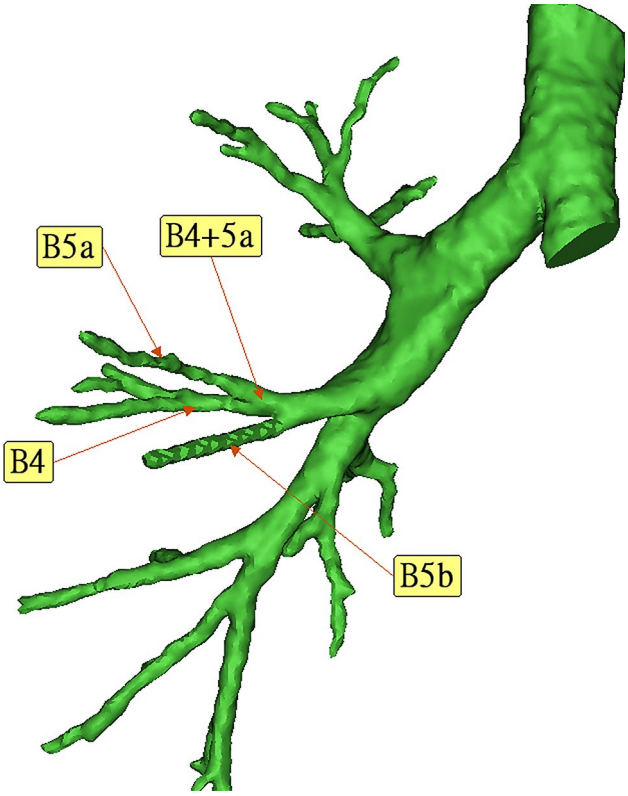

Fig. 2 3D model of the B_{5a}+B_4 cotrunk of the middle lobe of the right lung

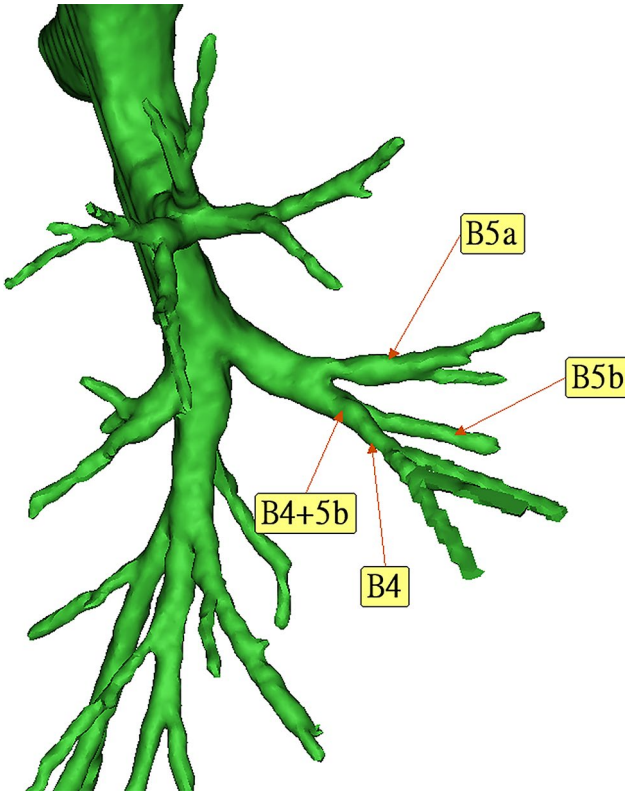

Fig. 3 3D model of the B_{5b}+B_4 cotrunk of the middle lobe of the right lung

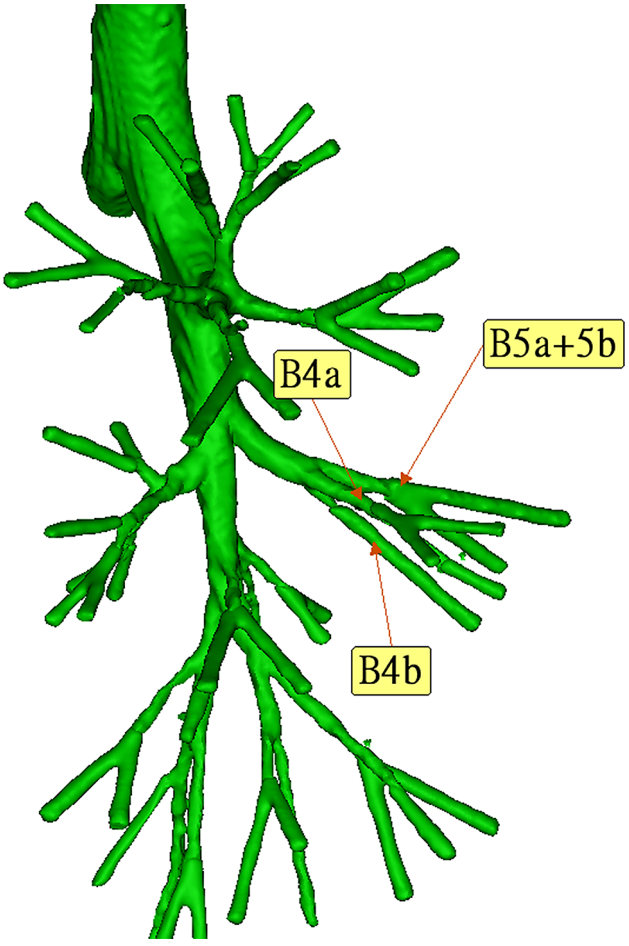

Fig. 4 3D model of the B_{4a}, B_{4b}, B_{5a}+B_{5b} in the bronchial trifurcation of the middle lobe of the right lung

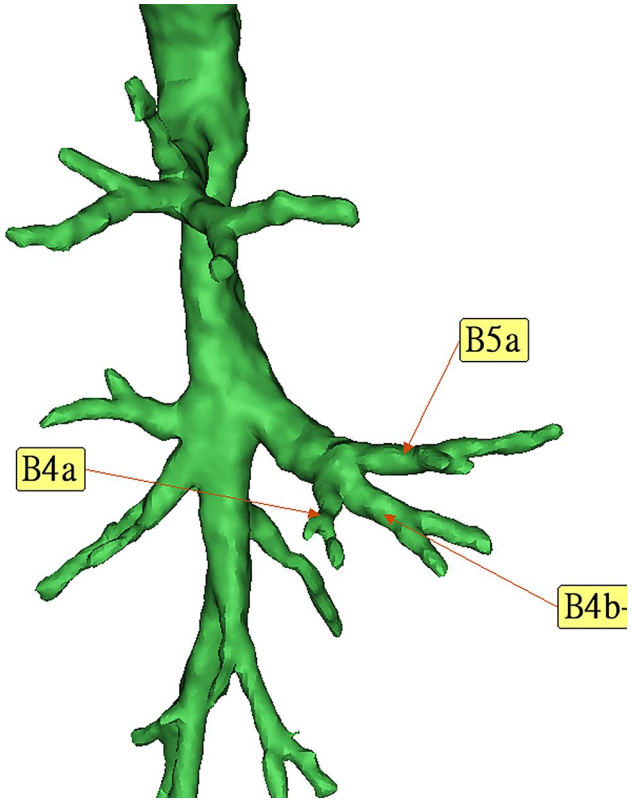

Fig. 5 3D model of the B_{4a}, B_{5a}, B_{4b}+B_{5b} in the bronchial trifurcation of the middle lobe of the right lung

B_{5b} showed an external-internal relationship in one case (0.2%) (Fig. 10).When B_4 and B_5 were in an upward and downward relationship, there were the following classifications: 1. B_{4a} and B_{4b} showed an external and internal relationship, and B_{5a} and B_{5b} showed an upward and downward relationship in 32 cases (5.9%) (Fig. 11); There were 19 cases (3.5%) of B_{4a} and B_{4b}, and B_{5a} and B_{5b} (Fig. 12);3. B_{4a} and B_{4b} were in an up-and-down relationship, and B_{5a} and B_{5b} were in an up-down relationship in one case (0.2%) (Fig. 13).In this paper, there is no case where B_{4a} and B_5 are in an upward and downward relationship, B_{4a} and B_{4b} are in an upward and downward relationship, and B_{5a} and B_{5b} are in an external and internal relationship. In addition, 23 cases (4.3%) were found to have a spatial relationship with B_4 and B_5 in the middle lobe of the right lung, similar to the B_4 and B_5 lingual subtypes of the upper lobe of the left lung. (Fig. 14)

Discussion

Lobectomy and segmental resection is the standard surgical method for the treatment of lung diseases, and it is essential to have a good grasp of the anatomy and special variations of the bronchi in the lungs to improve the safety and quality of the surgery [11, 12]. The anatomical types of bronchial branches of lung segments and subsegments are complex and diverse, and for patients with early-stage lung cancer who currently need to undergo lobectomy or even segmentectomy, the possible anatomical variations will become an obstacle to the identification of anatomical structures during surgery, and may even cause misjudgment. Traditional autopsy and

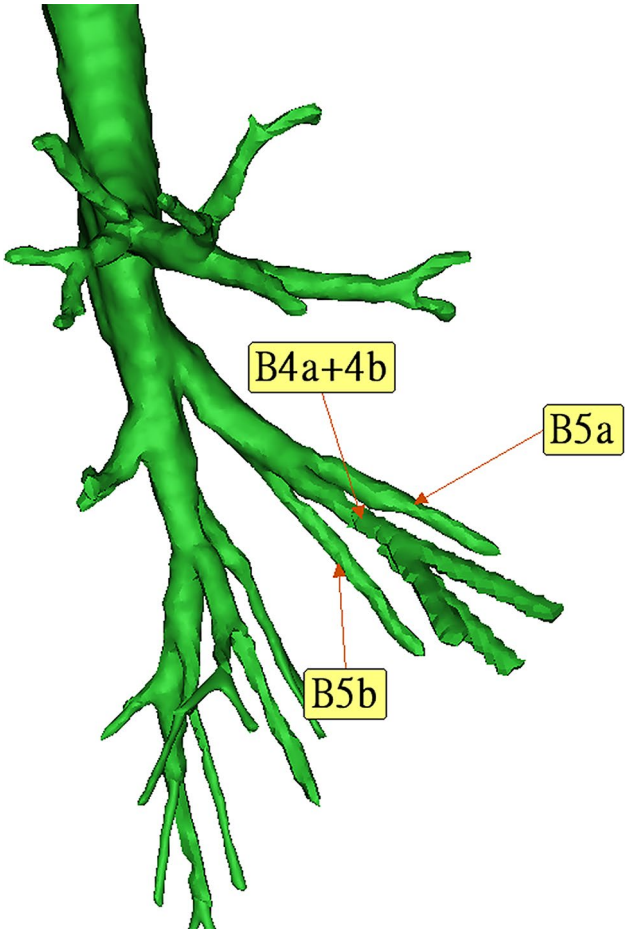

Fig. 6 3D model of the B_{5a}, B_{5b}, B_{4a}+B_{4b} in the bronchial trifurcation of the middle lobe of the right lung

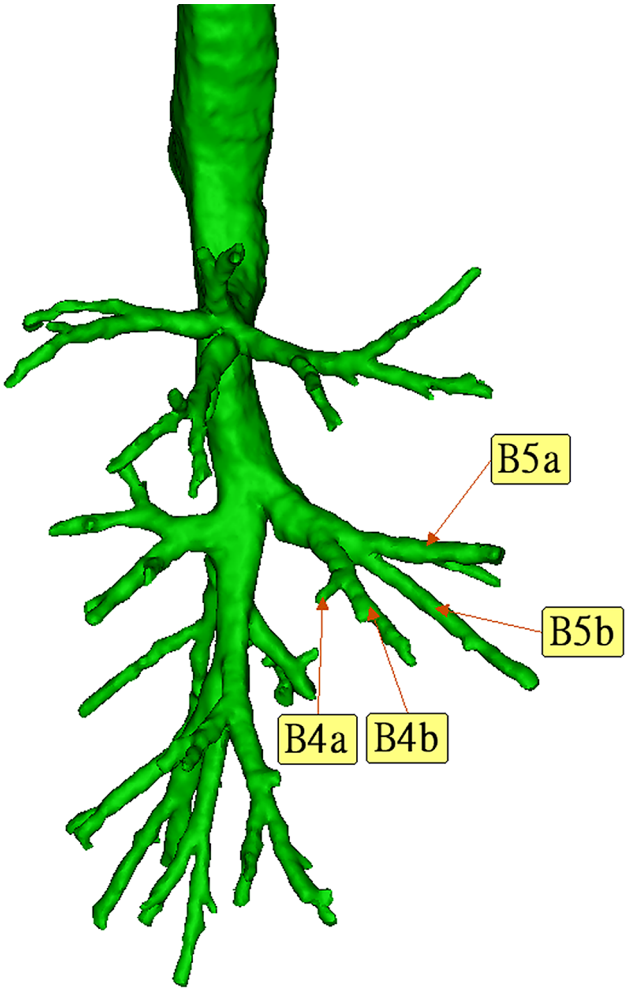

Fig. 7 A 3D model of the middle lobe bronchi of the right lung in which B_4 and B_5 are in an external-internal relationship, B4a and B4b are externally and internally, and B_{5a} and B_{5b} are in an up-down relationship

tomotomy can only observe bronchial anatomy from a cross-sectional, coronal or sagittal plane, but CT 3D reconstruction technology can more intuitively display the branch types and anatomical variations of the bronchi in the lung segment, which provides a great guarantee for preoperative planning and intraoperative safety [13–15] (Table 2).

In recent years, thoracoscopic sublobectomy has been shown to be safe and effective, and Hirohisa Kato et al. studied 357 consecutive patients who underwent thoracoscopic anatomical sublobectomy for lung cancer between March 2005 and May 2020, suggesting that thoracoscopic subsegmental resection can be used for ground-glass opacity-dominated lung cancer < 1.5 cm, if adequate margins can be ensured.

Based on CT data, the bronchi of the middle lobe of the right lung was reconstructed and analyzed, and the dissection of the bronchi of the middle lobe of the right lung was systematically studied. In this study, the classification methods of multiple studies were combined to classify and statistically analyze the anatomy of the middle lobe of the right lung in the most convenient way for surgeons to operate [16]. A meta-analysis of patients with operable stage IA non-small cell lung cancer was performed by Liwei Song et al. on subsegmentectomy versus segmentectomy, with a total of 325 patients undergoing subsegmentectomy and 904 patients undergoing segmentectomy participating in the analysis. Suggests that perioperative outcomes for subsegmentectomy and segmentectomy are comparable. Subsegmental resection may be an alternative treatment for deep tumors that are less than 1.5 cm in size and consist primarily of ground-glass opacities (GGOs) [17]. Xiayi Lv et al. studied the survival rates of 861 patients with early right middle lobe non-small cell lung cancer after lobectomy and sublobectomy, and the prognosis of lobectomy and sublobectomy was comparable for patients with stage IA right middle lobe ≤ 1 cm NSCLC [18]. Zhang Min et al. performed thoracoscopic right middle lobe subsegmentectomy in 94 patients, and confirmed that thoracoscopic right middle lobe subsegmentectomy was feasible

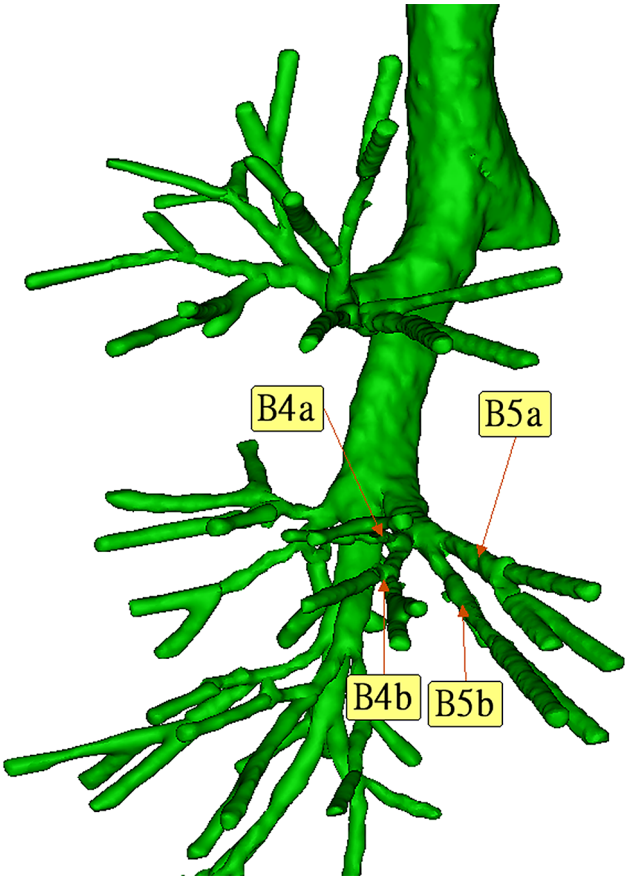

Fig. 8 A 3D model of the bronchi B_4 and B_5 in the middle lobe of the right lung, B_{4a} and B_{4b} in an up-down relationship, and B_{5a} and B_{5b} in an up-down relationship

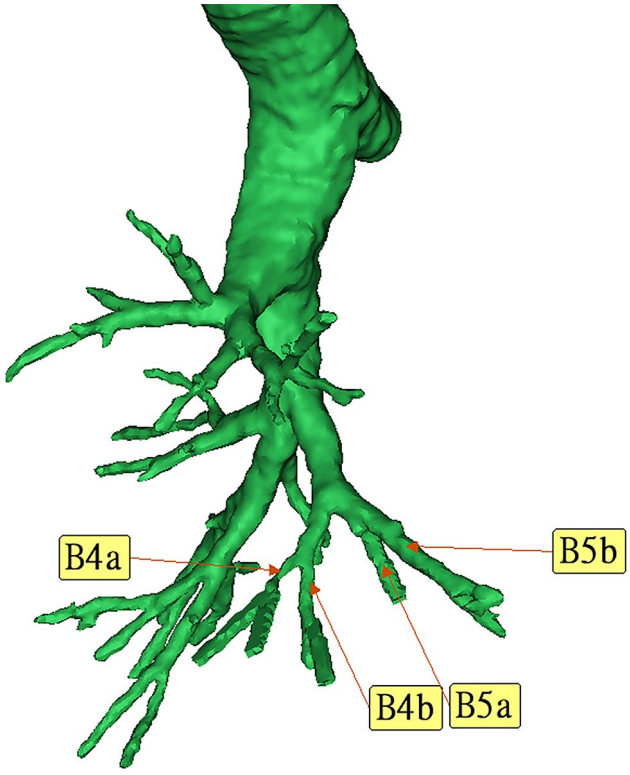

Fig. 9 A 3D model of the middle lobe bronchi of the right lung in which B_4 and B_5 are externally and internally, B_{4a} and B_{4b} are externally and internally, and B_{5a} and B_{5b} are externally and internally

and safe. Preservation of lung parenchyma may be valuable in patients with non-invasive lung cancer, multiple lung cancer, and benign disease [19]. Based on the above research, this study was the first to reconstruct and analyze the bronchi of the middle lobe of the right lung based on CT data, and systematically studied the anatomy of the bronchi of the middle lobe of the right lung. In this study, the classification methods of multiple studies were combined to classify and statistically analyze the anatomy of the middle lobe of the right lung in the most convenient way for the surgeon to operate and preserve as much lung function as possible.

Nagashima et al., analyzing CT 3D reconstructed images from 270 patients, found that all the middle lobe bronchus of the right lung were single-branched, i.e., $B_4 + B_5$.[20]The results of this study are consistent with this, and the anatomical types of the middle bronchi of the right lung are further divided into two-branched and three-branched types according to the number of branches, and the anatomical types of the middle bronchi of the right lung are further supplemented. Among the two-branched types, there is also co-trunk, the most common is B4b + B5 co-trunk. The number of B_{4a}, B_{5a}, $B_{4b} + B_{5b}$ and B_{4a}, B_{4b}, $B_{5a} + B_{5b}$ was the same in the three-branch type. In addition, the spatial relationships between the bronchial tubes are also supplemented, the most common of which are B_4 and B_5 in the external-internal relationship, B_{4a} and B_{4b} in the external-internal relationship, and B_{5a} and B_{5b} in the upper and lower relationship.

Ghaye et al. found that 23% of the B_4, B_5 bronchi in the middle lobe of the right lung have an up-and-down

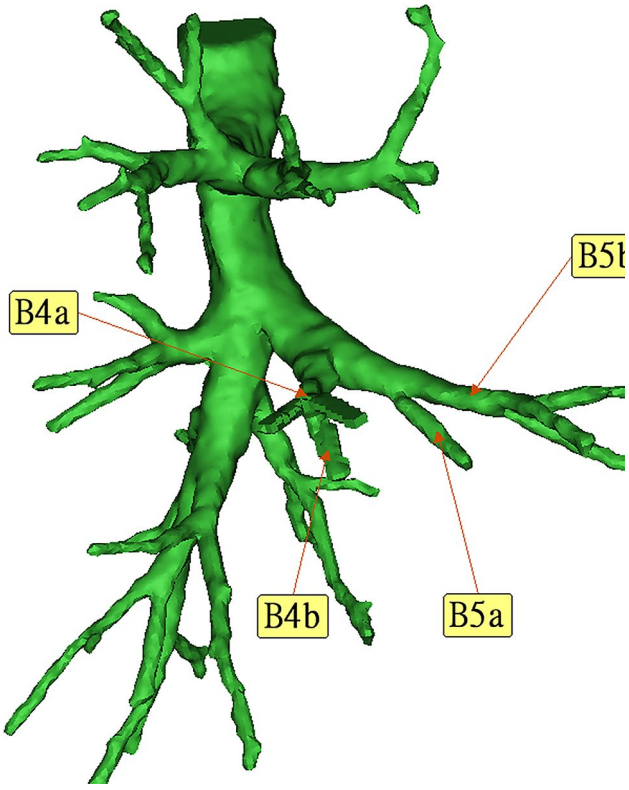

Fig. 10 A 3D model of the bronchi B_4 and B_5 in the middle lobe of the right lung, B_{4a} and B_{4b} in an up-down relationship, and B_{5a} and B_{5b} in an external-internal relationship

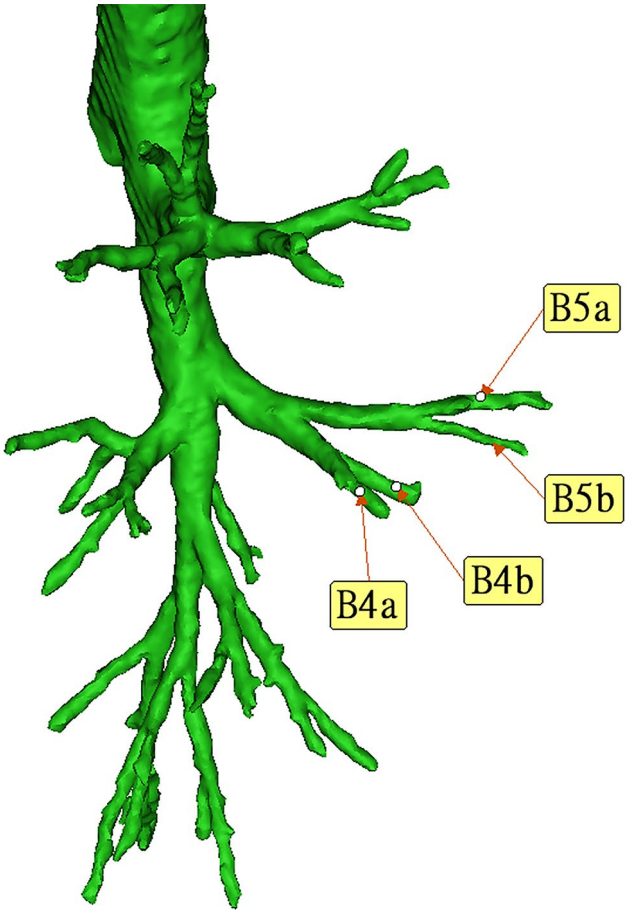

Fig. 11 A 3D model of the middle lobe bronchus of the right lung in which B_4 and B_5 are in an up-down relationship, B_{4a} and B_{4b} are in an external-internal relationship, and B_{5a} and B_{5b} are in an up-down relationship

position relationship similar to that of the B_4, B_5 bronchi in the tongue segment of the left upper lobe; [21]However, in this study, only 23 patients (4.3%) were found to have an up-and-down position relationship similar to that of B_4 and B_5 bronchi in the tongue segment of the left upper lobe, which was much lower than reported by Ghaye et al. We analyzed this may be related to the small sample size (30 cases) of Ghaye et al. Due to the small size of the right middle lobe and the smaller residual lung tissue after lung segment surgery, complications such as torsion and atelectasis are prone to occur after surgery, so the preoperative thin-slice CT examination of the chest and the three-dimensional reconstruction of CT are performed to correctly evaluate the anatomical type of the lingual bronchi of the middle lobe of the right lung and clarify the spatial position relationship of the bronchi of the lung segment, which plays an important role in guiding the successful implementation of the operation.

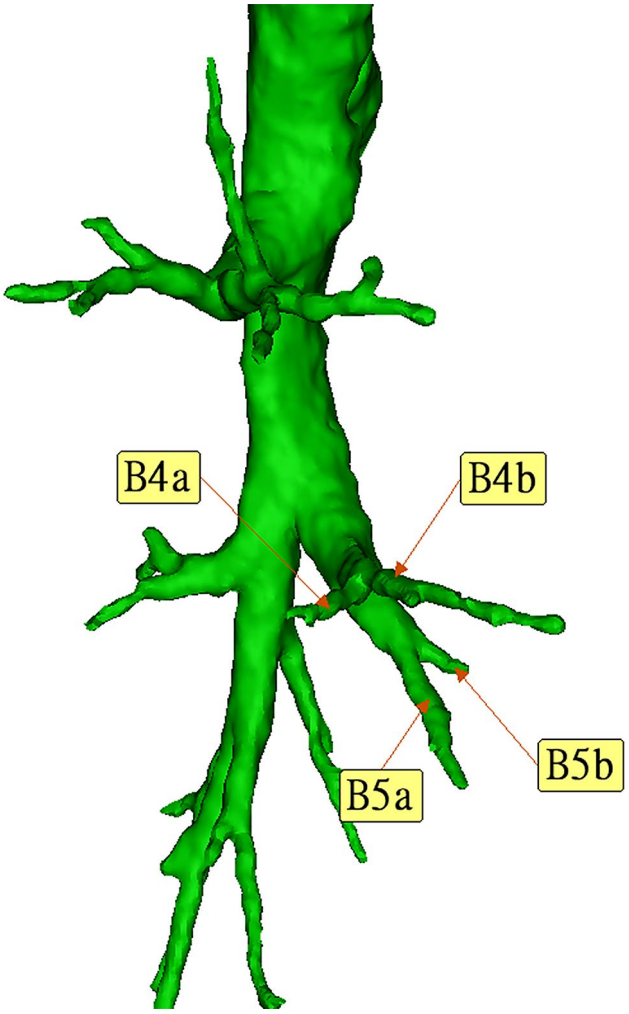

Fig. 12 A 3D model of the middle lobe bronchi of the right lung in which B_4 and B_5 are in an upper-inferior relationship, B_{4a} and B_{4b} are in an external-internal relationship, and B_{5a} and B_{5b} are in an external-internal relationship

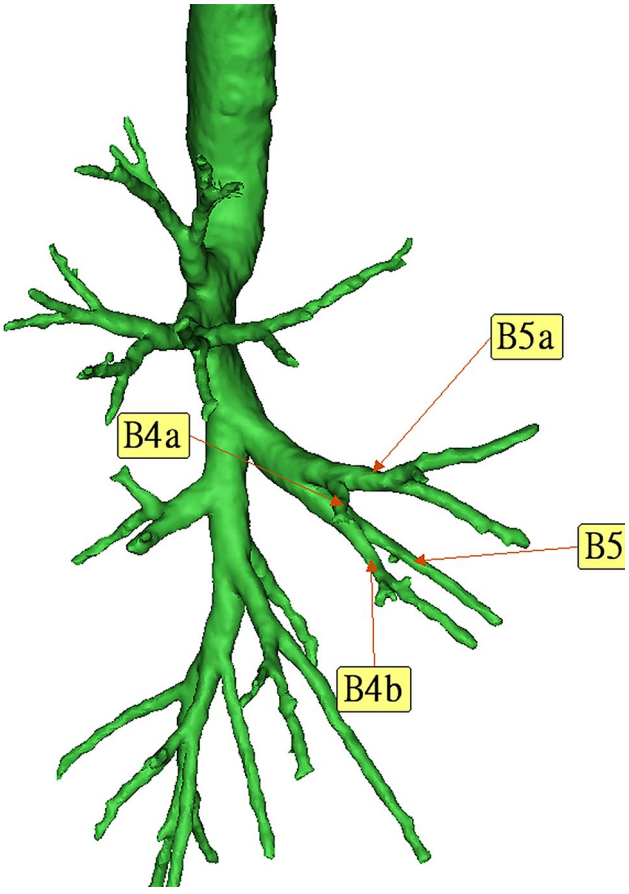

Fig. 13 A 3D model of the middle lobe bronchi of the right lung in which B_4 is in an up-down relationship with B_5, B_{4a} is in an up-down relationship with B_{4b}, and B_{5a} is in an up-down relationship with B_{5b}

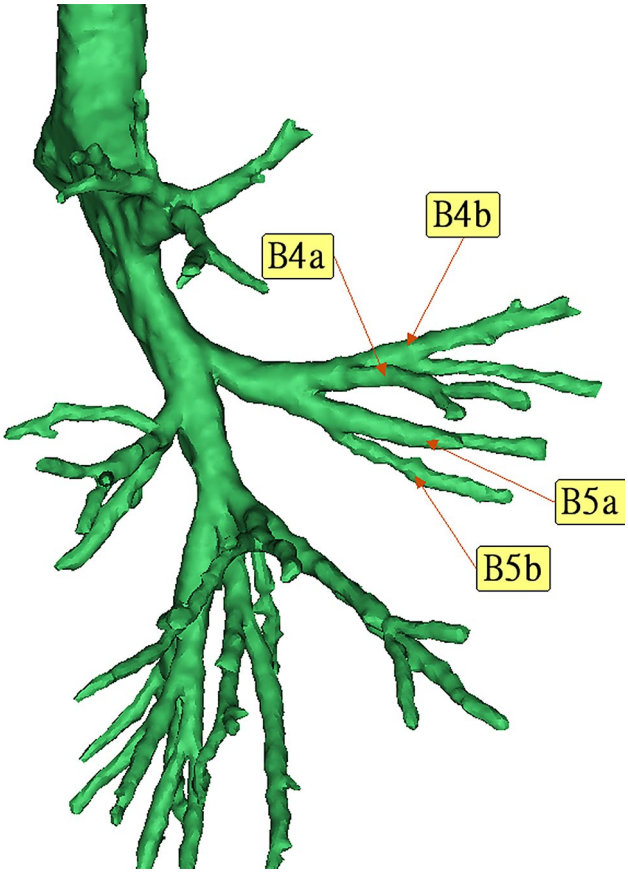

Fig. 14 A 3D model of the bronchial B_4 and B_5 of the middle lobe of the right lung resembling the bronchial structure of the lingual segment

Table 2 The Spatial relationship and proportion of bronchial in the right middle lobe of the 541 patients

Bronchial spatial relationships of the right middle lobe		NO.	%
B4 + B5 (external-internal)	B_{4a+4b}(external-internal) B_{5a+5b}(up-down)	416	76.9
	B_{4a+4b}(up-down) B_{5a+5b}(up-down)	8	1.5
	B_{4a+4b}(external-internal) B_{5a+5b}(external-internal)	8	1.5
	B_{4a+4b}(up-down) B_{5a+5b}(external-internal)	1	0.2
B4 + B5 (up-down)	B_{4a+4b}(external-internal) B_{5a+5b}(up-down)	32	5.9
	B_{4a+4b}(external-internal) B_{5a+5b}(external-internal)	19	3.5
	B_{4a+4b}(up-down) B_{5a+5b}(up-down)	1	0.2
Three-branched type		11	11
other		49	45

Conclusion

In summary, the middle lobe and subsegment bronchi of the right lung have extremely complex anatomical typologies and rare variations, and we used a large number of CT 3D reconstructed images to explore and name the bronchial pattern of the middle lobe of the right lung. Thoracic surgeons should be familiar with the various anatomical types and subsegmental anatomical types and relatively common variants in order to guide delicate lobectomy and segmental resection. There are some limitations in this study, this study is a retrospective study, and the sample size is relatively small.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13019-025-03402-0.

Supplementary Material 1

Acknowledgements
Not applicable.

Author contributions
WW completed the main design and conception of the study. ZB complete the collection of clinical data. ZB and WW complete the collection of data. ZB and WW collected the pathological data of patients. ZB and WW integrate the data. ZB and WW analyze and interpret the data. WW processes the data graphics. ZB and WW drafted the first draft of the article, and DG and WW made final revisions to the article. All authors have read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The Ethical Committee of Hebei General Hospital approved this study (Ethics approval number:2024-LW-070). We confirm the confidentiality of the data maintained and compliance with the "Declaration of Helsinki". Informed consent was waived due to the retrospective nature of the study.

Consent for publication
All data is presented with the consent of the person in question and may be published.

Competing interests
The authors declare no competing interests.

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