Surgical and Radiologic Anatomy (2019) 41:335–338
https://doi.org/10.1007/s00276-019-02199-7

ANATOMIC VARIATIONS

An anatomical study of the right bronchial tree using multi-detector computed tomography

Min Huang[1] · Tao Wang[2] · Ximing Wang[3] · Xinya Zhao[3]

Received: 15 October 2018 / Accepted: 31 January 2019 / Published online: 6 February 2019
© Springer-Verlag France SAS, part of Springer Nature 2019

Abstract

Purpose The aims were to study the pattern of right bronchial tree with multi-detector CT.

Methods 238 patients were enrolled. The three-dimensional bronchial tree images were acquired using the post-processing technique of CT.

Results There were mainly four types for right superior lobe bronchial tree, i.e., (140/238, B1–B2–B3); (44/238, B1 + 2, B3); (28/238, B2, B3); (22/238, B1, B2 + 3). There were two types for right middle lobe bronchial tree, i.e. (229/238, B4, B5); trifurcation of right middle lobe bronchi (9/238). There were mainly four types for right inferior lobe bronchial tree, i.e., (135/238, B6, B7, B8, B9, B10); (42/238, B6, B7, B8, B10); (25/238, B6, B7, B8 + 9, B10); (21/238, B6, B7, B8-B9-B10).

Conclusions The present study describes variations in the anatomy of the right bronchial tree, and reveals that there were mainly four types for right superior lobe bronchial tree, two types for right middle lobe bronchial tree, and four types for right inferior lobe bronchial tree.

Keywords Right bronchial tree · Anatomy · Computed tomography

Introduction

The anatomy of the tracheobronchial tree, described in Gray's anatomy [9], considers only the most common anatomical pattern, without inclusion of anatomical variations. As such, in daily practice, radiologists and thoracic surgeons are often confused when they encounter other ramifications of the bronchi on radiological images. Improved knowledge of the anatomical variants of the tracheobronchial tree would help radiologists in interpretation of radiological images and surgeons in performing safe and accurate pulmonary segmentectomy.

The anatomy of the bronchi has been studied extensively using bronchography [7], transverse computed tomography (CT) [5], and bronchoscopy [1]. However, the optimal technique to evaluate the anatomical pattern of the tracheobronchial tree in vivo remains controversial. Advances in multi-detector CT have broadened the potential use of imaging to study the anatomy of the airway by offering various image reconstruction techniques, including shaded-surface display (SSD) and volume rendering [8]. The SSD technique uniquely provides a 3-dimensional (3D) panoramic view of the bronchial tree and, therefore, could be useful to study variations in the anatomy of the bronchial tree. Using the rare patterns of the right tracheobronchial tree reported in a previous study as a starting point [10], our aim in this study was to characterize the common anatomical patterns of the right bronchial tree from 3D reconstruction of multi-detector CT images.

✉ Xinya Zhao
zhaoxinya2000@126.com

1 Department of Laboratory, Shandong Provincial Hospital Affiliated to Shandong University, 324#, Jingwu Road, Jinan 250021, Shandong, China

2 Shandong Medical Imaging Research Institute, Shandong University, 324#, Jingwu Road, Jinan 250021, Shandong, China

3 Department of Radiology, Shandong Provincial Hospital Affiliated to Shandong University, 324#, Jingwu Road, Jinan 250021, Shandong, China

Materials and methods

Study group

Our retrospective analysis was based on the CT images of 238 patients, without endobronchial or pulmonary lesions. The study sample included 149 men, 24–94 years of age [mean age 48.4 years, standard deviation (SD) 12.2 years], and 89 women, 19–75 years of age (mean age 46.2 years, SD 6.1 years). Patients were randomly selected from the cohort of consecutively registered Chinese out-patients who presented to our hospital with coughing, dyspnea, and/or hemoptysis between June 2015 and May 2016 and underwent diagnostic CT for lung tumors, pneumonia, or bronchiectasis.

Imaging technique

Conventional thoracic CT (Siemens Sensation 64, collimation 64 × 0.6 mm, pitch 1.0, rotation time 0.5 s, 120 kV, and 70–120 mAs) imaging was used in all cases. The 3D bronchial trees were obtained using the SSD technique. Multiplanar reconstructions (MPR), which permits the optimal rotation of the image in different planes (axial, coronal, or sagittal), and virtual bronchoscopy (VB), that produces endobronchial views as conventional bronchoscopy, were also used to identify the branching patterns of segmental bronchi.

Image analysis

Three radiologists, having 17, 15, and 10 years of thoracic radiology experience, reviewed all bronchial tree and MPR images, with any differences in interpretation resolved by consensus.

Results

Bronchial tree of the right superior lobe

We identified four main anatomical patterns of the bronchial tree of the right superior lobe (Table 1). The most common type, identified in 140 of the 238 cases (type I, 58.8%), was characterized by a trifurcation of the right superior lobe bronchi into apical (B1), posterior (B2) and anterior (B3) segments (Fig. 1a). In another 44 cases (type II, 18.5%), the bronchus bifurcated into a B3 segment, with the common stem bifurcating into apical and posterior (B1 + 2) segments (Fig. 1b). In 28 cases (type III, 11.7%), the bronchus bifurcated into B2 and B3 segments (Fig. 1c). In 22 cases (type IV, 9.24%), the bronchus bifurcated into a B1 segment, with the common stem bifurcating into posterior and anterior (B2 + 3) segments (Fig. 1d). The remaining four cases presented with rare anatomical variants having previously been described [10].

Table 1 Main anatomical patterns of the right bronchial tree

Types	Patterns	Number of patients total/male (%)/female (%)
Right superior lobe		
I	B1–B2–B3	140/87 (62.1%)/53 (37.9%)
II	B1 + 2, B3	44/26 (59.1%)/18 (40.9%)
III	B2, B3	28/16 (57.1%)/12 (42.9%)
IV′	B1, B2 + 3	22/18 (81.8%)/4 (18.2%)
Right middle lobe		
I	B4, B5	229/161 (70.3%)/68 (29.7%)
II	Trifurcation	9/5 (55.5%)/4 (44.5%)
Right inferior lobe		
I	B6, B7, B8, B9, B10	135/84 (62.2%)/51 (37.8%)
II	B6, B7, B8, B10	42/28 (66.7%)/14 (33.3%)
III	B6, B7, B8 + 9, B10	25/16 (64%)/9 (36%)
IV	B6, B7, B8–B9–B10	21/13 (61.9%)/8 (38.1%)

Bronchial tree of the right middle lobe

In 229 cases (type I, 96.2%), the bronchus of the right middle lobe bifurcated into a lateral (B4) and medial (B5) segment (Fig. 2a). In the remaining nine cases (type II, 3.8%), the bronchus trifurcated into three bronchi (Fig. 2b).

Bronchial tree of the right inferior lobe

There were four main anatomical patterns of the bronchial tree of the right inferior lobe (Table 1). In the most common type, observed in 135 cases (type I, 56.7%), the superior (B6), the medial (B7), and the anterior (B8) segmental bronchus arose separately, with the basal trunk bifurcated into a lateral (B9) and a posterior (Bl0) segment (Fig. 3a). In 42 cases (type II, 17.6%), the B6 and B7 segments originated separately, and the basal trunk bronchi bifurcated into B8 and B10 segments (Fig. 3b). In these cases, the B9 segment was difficult to identify. In 25 cases (type III, 10.5%), the B6 and B7 segments arose separately, and the basal trunk bronchi bifurcated into a B10 segment, with the stem bifurcating into B8 and B9 (B8 + 9) segments (Fig. 3c). In 21 cases (type IV, 8.8%), the B6 and B7 segments branched separately, with the basal trunk bronchus trifurcated into

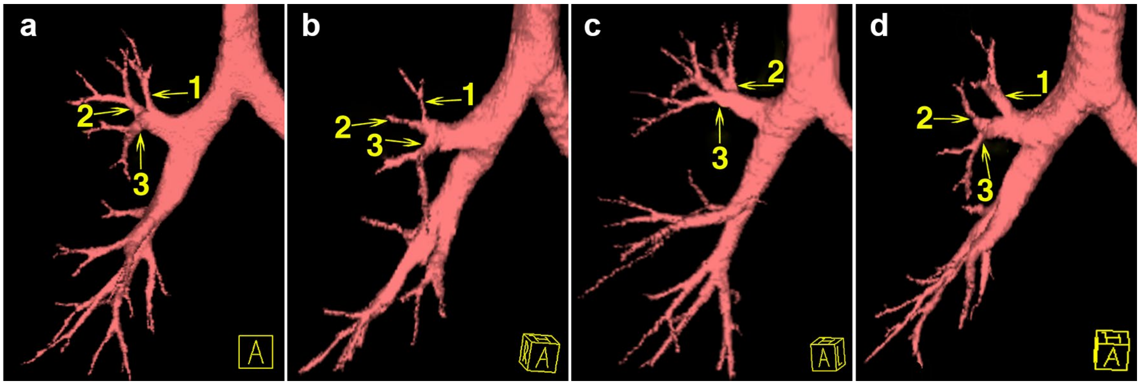

Fig. 1 The pattern of the right superior lobe bronchial tree: **a** B1–B2–B3; **b** B1 + 2, B3; **c** B2, B3; and **d** B1, B2 + 3

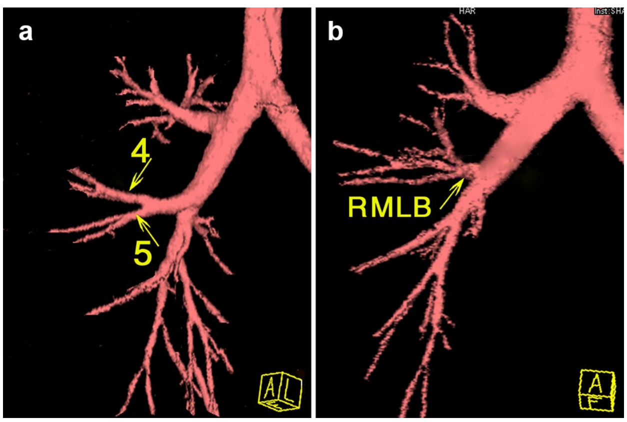

Fig. 2 The pattern of the right middle bronchial tree: **a** B4, B5; and **b** trifurcation

B8, B9, and B10 segments (Fig. 3d). The remaining 15 cases presented with rare anatomical variants that have previously been described [10].

Discussion

Normal tracheobronchial development is initiated at embryological day 24–26, as a median bulge on the ventral wall of the pharynx that develops at the caudal end of the laryngotracheal groove. At 26–28 days, this bulge gives rise to right and left lung buds. At 28–30 days, the lung buds elongate into primary bronchi. At 30–32 days, the five lobar bronchi appear as a monopodial outgrowth of the primary bronchi. The lobar bronchi elongate at 32–34 days and then rapidly branch to form all segmental bronchi by 36 days [2], at which time, anatomical variation in the airway may occur.

Several imaging approaches have been introduced to study the anatomy of the airway in vivo, including bronchography [7], transverse CT [5] and bronchoscopy [1]. Bronchography uses 2-dimensional imaging and, thus, overlap between bronchi that run 3-dimensional space is unavoidable, which introduces inaccuracies. The use of transverse CT images requires spatial integration of partial data collected from multiple sections, a process that can be arduous. Lastly, bronchoscopy can only provide endobronchial

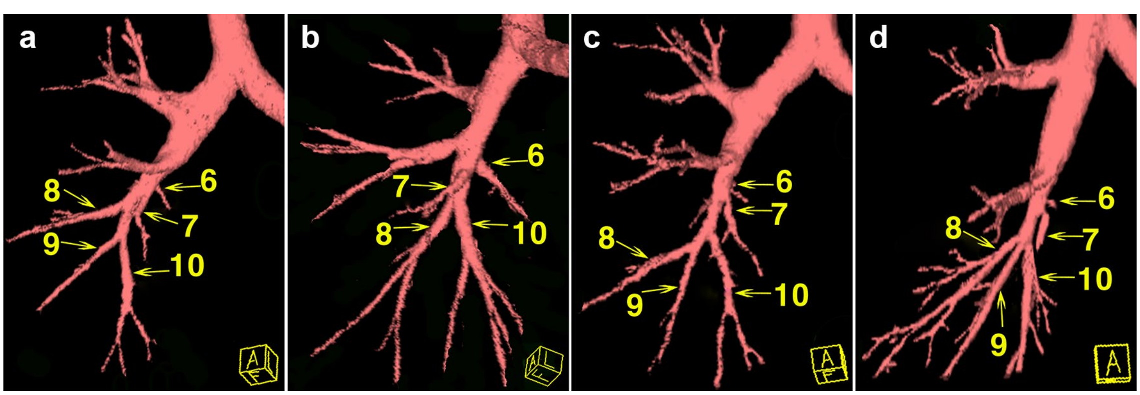

Fig. 3 The pattern of the right inferior lobe bronchial tree: **a** B6, B7, B8, B9, B10; **b** B6, B7, B8, B10; **c** B6, B7, B8 + 9, B10; and **d** B6, B7, B8–B9–B10

views. The present study provided high quality 3-dimensional (3D) images, created using the multi-detector row CT post-processing technique and VB, which simulated the findings of conventional bronchoscopy. The anatomy of the bronchi could, thus, be studied using extrabronchial and endobronchial views, using the 3D bronchial tree and VB images, respectively, allowing the bronchial branching patterns to be understood at a glance. Moreover, the 3D images of the bronchial tree could be rotated in 3D space, therefore, overcoming the limitations of 2D imaging systems, such as bronchography and transverse CT and providing a more anatomically meaningful display of the complex structure of the airways. Of importance, as advance in multi-detector CT allows acquisition of isotropic data [8], the reconstruction of 3D images can be obtained from routine 64-slice thoracic CT examination that is used for the purpose of clinical diagnosis. As a result, anatomical images used in our analysis were easier to gather than anatomical specimen.

Lung screening using high resolution CT has recently become widespread, with this technique providing a greater detection of small lung lesions that are difficult to visualize on routine chest radiography [6]. Our identification of various anatomical patterns of the right bronchial tree could be helpful to radiologists to recognize all bronchopulmonary segments and, therefore, accurately report the location of focal lesions in the lung. The prognosis of selected patients who undergo sublobar resection for small-sized non-small cell lung cancer is not inferior to those treated using lobectomy. Moreover, segmentectomy preserves more lung function than does lobectomy [4]. However, segmentectomy is technically more difficult to perform than standard lobectomy because of the anatomical complex of the lung, featuring both vascular and bronchial structures that vary at segmental levels. Therefore, pre-operative knowledge of the anatomy of tracheobronchial trees may have important implications for surgeons to perform safe and accurate pulmonary segmentectomy. Moreover, 3D images may provide an accurate “roadmap” to guide fiber optic bronchoscopy [3].

Conclusions

The present study describes variations in the anatomy of the right bronchial tree, with four main types identified for the right superior lobe bronchial tree, two for the right middle lobe bronchial tree, and four for the right inferior lobe bronchial tree. Knowledge of the detailed anatomy of the bronchial tree may have important implications in improving radiologic interpretation of images and the performance of safe and accurate pulmonary segmentectomy.

Acknowledgements This work was supported by Shandong Province Science and Technology Development Projects (no. 2012GCG21812), and Shandong Provincial Medical Health Technology Development Projects (no. 2017WS472).

Author contributions MH, TW, XW, and XZ have made substantial contributions to the conception and design of the study, acquisition of data, or analysis and interpretation of data. All the authors have been involved in drafting the article or revising it critically for important intellectual content. All the authors have approved the final version to be published.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the ethics committee of Shandong Provincial Hospital Affiliated to Shandong University.

References

1. Beder S, Küpeli E, Karnak D, Kayacan O (2008) Tracheobronchial variations in Turkish population. Clin Anat 21:531–538
2. Ghaye B, Szapiro D, Fanchamps JM, Dondelinger RF (2001) Congenital bronchial abnormalities revisited. RadioGraphics 21:105–119
3. Horton KM, Horton MR, Fishman EK (2007) Advanced visualization of airways with 64-MDCT: 3D mapping and virtual bronchoscopy. AJR 189:1387–1396
4. Keenan RJ, Landreneau RJ, Maley RH Jr, Singh D, Macherey R, Bartley S, Santucci T (2004) Segmental resection spares pulmonary functioning in patients with stage I lung cancer. Ann Thorac Surg 78:228–233
5. Naidich DP, Zinn WL, Ettenger NA, McCauley DI, Garay SM (1988) Basilar segmental bronchi: thin-section CT evaluation. Radiology 169:11–16
6. Nakata M, Sawada S, Yamashita M, aeki H, Kurita A, Takashima S, Tanemoto K (2005) Objective radiologic analysis of ground-grass opacity aimed at curative limited resection for small peripheral non-small cell lung cancer. J Thorac Cardiovasc Surg 129:1226–1231
7. Roux BT (1962) The bronchial anatomy of the left upper lobe. J Thorac Cardiovasc Surg 44:216–224
8. Salvolini L, Bichi Secchi E, Costarelli L, De Nicola M (2000) Clinical applications of 2D and 3D CT imaging of the airways: a review. Eur J Radiol 34:9–25
9. Williams PL (1995) Trachea and bronchi. In: Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE, Firguson MW (eds) Gray’s anatomy, 38th edn. Churchill Livingstone, New York, pp 1653–1657
10. Wang T, Meng M, Huang M, Zhao X (2018) Variations of right bronchial tree: a study with multi-detector CT. Surg Radiol Anat 40:955–958

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.