Respiratory Medicine
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Jeffrey P. Kanne *Editor*

Clinically Oriented Pulmonary Imaging

Humana Press

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Respiratory Medicine

Series Editor

Sharon I. S. Rounds

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To Drs. J. David Godwin, Eric J. Stern, Julie E. Takasugi, John R. Mayo, and Nestor L. Müller, all of whom mentored me and taught me to recognize the beauty hiding beneath all of the "white stuff" in the lungs.

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Preface

Imaging is central to the diagnosis and management of patients with known or suspected pulmonary disease. Advances in imaging technology, particularly computerized tomography (CT), have broadened our understanding of pulmonary disease and have changed how we care for our patients.

Chest radiography remains the most commonly performed medical imaging examination because it is widely available, relatively inexpensive, uses very low doses of ionizing radiation, and often can answer the clinical question at hand. Radiography has been enhanced by the transition from film-screen to digital imaging and the subsequent electronic distribution of images and radiologic reports. Newer technologies such as dual-energy radiography and computer-aided detection (CAD) can further enhance the utility of radiography.

The impact that CT has had on our understanding of pulmonary disease cannot be summarized in this brief introduction. CT has become a standard component of assessing respiratory tract disease. With current scanner technology, volumetric high-resolution CT (HRCT) images can readily be generated from routine chest CT scans at the time of imaging with little or no change in acquisition parameters. In fact, some institutions, such as mine, routinely generate thin-section images with all chest CT scans performed. CT pulmonary angiography has changed the paradigm for evaluating patients with suspected pulmonary thromboembolic disease, providing more definitive diagnosis and frequently identifying other causes of patients' presenting signs and symptoms. CT is also used to guide transthoracic needle biopsies.

The utility of magnetic resonance (MR) imaging for pulmonary disease has been relatively limited not only because of technical limitations but also because of overshadowing by the rapid growth in CT technology and applications. However, MR imaging techniques currently under development show promise for evaluation of the lungs. Furthermore, the ability to integrate cardiac and pulmonary imaging with a single MR imaging examination has the potential to revolutionize how we think about the intimate relationship between the heart and lungs.

While we can expect many exciting developments in pulmonary imaging in the future, one still needs to understand how imaging available today fits into the evaluation of our patients. This text aims to provide a clinically oriented approach to imaging the lungs and is by no means a comprehensive thoracic imaging text. Rather, the authors focus on specific clinical problems such as pulmonary thromboembolic disease, hemoptysis, or lung cancer, and they discuss the utility of imaging in addition to illustrating the imaging findings commonly encountered. It is my hope that the novice reader will find this text a useful introduction to how imaging fits into the evaluation of patients with known or suspected pulmonary disease. Additionally, more experienced readers may benefit from the focused approach to specific clinical problems or patient care settings and better understand the imaging tools available to improve care for their patients.

October 2011 Jeffrey P. Kanne

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Normal Thoracic Anatomy and Common Variants

1

Arlene Sirajuddin

Abstract

The normal anatomy of the thorax includes anatomy of the airways, lung parenchyma, pleura and fissures, mediastinum, great vessels, and diaphragm. This chapter will describe normal anatomy of the thorax as well as anatomic relationships of these structures to each other. Common congenital anatomic variants of the thorax will also be discussed.

Keywords

Normal thoracic anatomy • Variant anatomy • Trachea • Airways • Lung parenchyma • Mediastinum • Great vessels • Pleura • Hila • Diaphragm

Airways and Lung Parenchyma

Trachea and Central Airways

The trachea is an air-conducting tube that begins at the inferior margin of the cricoid cartilage, just below the level of the true vocal cords, and extends to the level of the carina, a ridge where the trachea bifurcates into right and left main bronchi. The trachea is lined by pseudostratified ciliated columnar epithelium. This epithelial layer also contains secretory goblet cells as well as specialized neuroendocrine cells. Fibroelastic lamina propria and the submucosa, made of both cartilage and muscle, compose the subepithelial tissue. There are approximately 16–22 C–shaped tracheal cartilages that are linked together by annular ligaments of fibrous and connective tissue. These cartilage rings can calcify with age (Fig. 1.1) [1, 2].

Sympathetic innervation of the trachea by the recurrent laryngeal nerve contracts the smooth muscle of the trachea, while parasympathetic innervation by the vagus nerve relaxes the smooth muscle of the trachea. The trachea vascular supply consists of tracheal branches of the inferior thyroid and bronchial arteries, and venous drainage is via the inferior thyroid veins. The lymphatics of the trachea drain into the pretracheal and right paratracheal nodes [1].

The shape of the trachea is always round in children. In adults, the extrathoracic portion of the trachea can be circular, elliptical, or horseshoe shaped. The intrathoracic adult trachea is usually round or oval. Tracheal length is approximately 5.7 cm long from birth to 3 years

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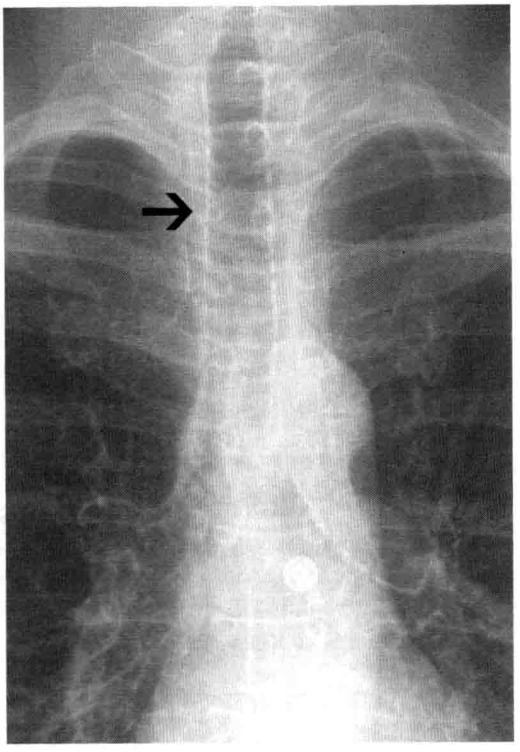

Fig. 1.1 Coned-down frontal radiograph shows a normal trachea bifurcating into right and left main bronchi. Note calcification in the wall of the trachea in this older individual. The arrow points to a normal right paratracheal stripe

and continues to lengthen until the age of 14 years. In boys, the trachea can continue to widen after the age of 14 years. In the adult, the tracheal length ranges from 8.5 to 15 cm, with an average length of 10 cm in women and 11 cm in men. Tracheal length is dynamic, and can change up to 3 cm with respiration [1]. Breatnach et al. describe normal tracheal measurements on PA and lateral radiographs as averaging 25 to 27 mm in men, and 21 to 23 mm in women, respectively. They report a lower limit of normal of 10 mm in women and 13 mm in men in both dimensions [3].

The trachea is essentially a midline structure. However, a study by Bhalla et al. describes normal deviation of the trachea to the right by up to 1.6 cm or to the left up to 0.7 cm [4]. The aortic arch also makes a mild impression on the intrathoracic trachea.

At the carina, the trachea bifurcates into the left and right main bronchi. The main bronchi subsequently give rise to the lobar bronchi. The right main bronchus gives rise to the right upper lobe bronchus, right middle lobe bronchus, and the right lower lobe bronchus. The left main bronchus gives rise to the left upper lobe bronchus, the lingular bronchus, and the left lower lobe bronchus. The lobar bronchi then give rise to segmental bronchi, listed below [5].

- right upper lobe: apical, anterior, posterior
- right middle lobe: medial, lateral
- right lower lobe: superior, anterior basal, medial basal, lateral basal, posterior basal
- left upper lobe: apicoposterior and anterior
- lingula: superior and inferior
- left lower lobe: superior, anteromedial basal, lateral basal, posterior basal

The anatomic relationships of the trachea, main bronchi, and the branching pattern of these airways are depicted in Fig. 1.2.

Several important landmarks have been described in relation to the lobar bronchi. At the level of the right upper lobe bronchus, the right superior pulmonary vein is reliably present just lateral to this bronchus (Fig. 1.3). Distal to the origin of the right upper lobe bronchus is a short segment of bronchus known as the bronchus intermedius, which lies directly posterior to the right pulmonary artery (Fig. 1.4). The bronchus intermedius gives rise to the right middle lobe and right lower lobe bronchi [5].

The left upper lobe bronchus arises at a lower level than the right upper lobe bronchus and forms a sling over which the left pulmonary artery crosses. The posterior wall of the left upper lobe bronchus is concave secondary to the presence of the left pulmonary artery (Fig. 1.4). The lingular bronchus has an oblique course and, thus, is not as clearly depicted on cross-sectional imaging. The descending left pulmonary artery always lies directly posterior to the lingular bronchus [5, 6]. The left lower lobe bronchus is similar to the right lower lobe bronchus, though its origin is higher [5].

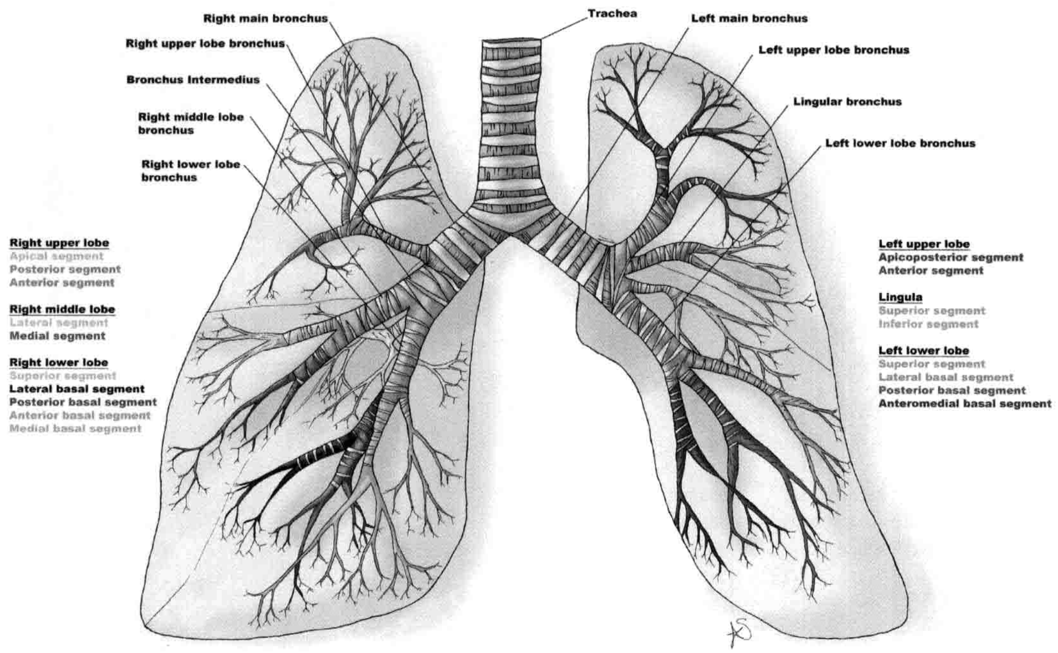

Fig. 1.2 Illustration depicting the relationship of the trachea, main bronchi, lobar bronchi, and segmental bronchi

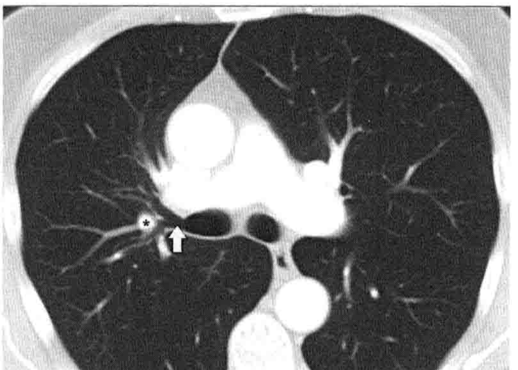

Fig. 1.3 Transverse computed tomography image shows the superior right pulmonary vein (*asterisk*) just lateral to the right upper lobe bronchus (*arrow*)

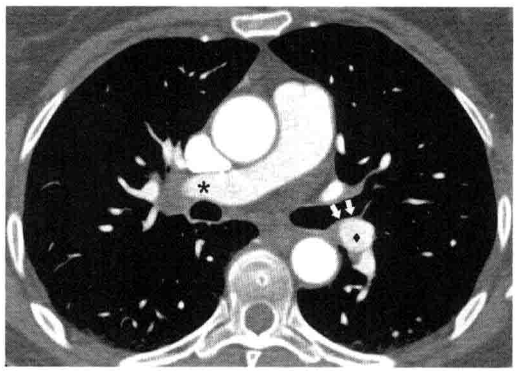

Fig. 1.4 Transverse computed tomography image shows the right pulmonary artery (*asterisk*) anterior to the bronchus intermedius. Also note the concave wall of the left upper lobe bronchus (*white arrows*) secondary to the left pulmonary artery (*diamond*)

Central Airway Anomalies

Anomalies of the airways include both major abnormalities of the lobar bronchi and minor abnormalities of the segmental bronchi. Bronchial anomalies are more common on the right [7]. These anomalies include displaced airways arising from nonstandard locations, supernumerary airways, absent or atretic airways, and airway abnormalities associated with abnormalities of situs.

The tracheal bronchus is a bronchus arising from the trachea, almost always on the right (Fig. 1.5), and is usually a displaced right upper lobe bronchus or displaced apical segmental

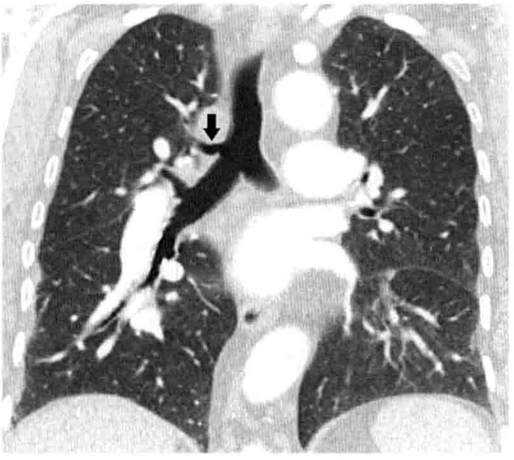

Fig. 1.5 Coronal reformatted computed tomography image demonstrates a tracheal bronchus (*arrow*) arising directly from the trachea

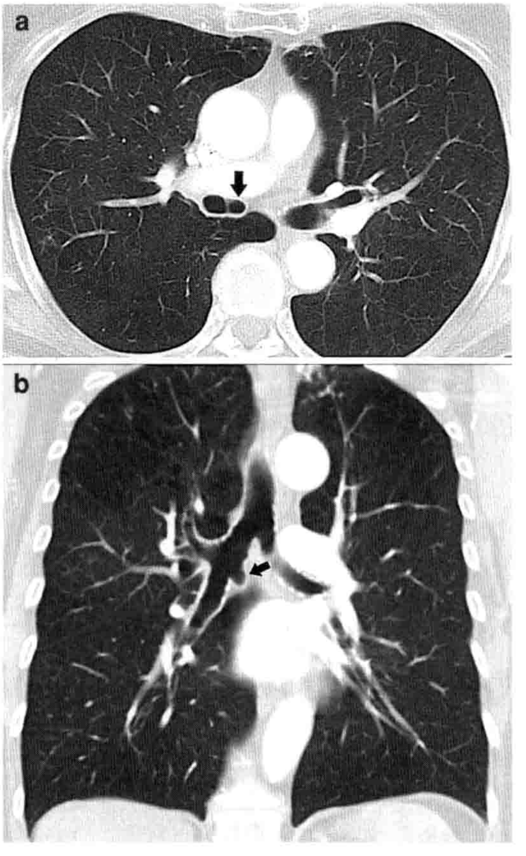

Fig. 1.6 **a** Transverse computed tomography image shows a cardiac bronchus (*arrow*) arising medially from the bronchus intermedius. **b** Coronal reformatted computed tomography image shows a blind-ending cardiac bronchus (*arrow*) arising from the medial aspect of the bronchus intermedius

bronchus. Occasionally, the tracheal bronchus is a supernumerary bronchus with a normal right upper lobe bronchus also present [8–12]. The lung tissue aerated by a supernumerary tracheal bronchus has been described as the tracheal lobe. A tracheal bronchus usually produces no signs or symptoms. However, it can be associated with infection, cough, dyspnea, and hemoptysis [9–12]. In children, it is a recognized cause of recurrent right upper lobe pneumonia [13].

A cardiac bronchus is a true supernumerary bronchus. It occurs in 0.09–0.5% of patients and is more common in men. It is a short segment bronchus arising from the medial wall of the bronchus intermedius. This bronchus usually is blind ending but occasionally supplies a rudimentary lobe of lung tissue (Fig. 1.6). As with the tracheal bronchus, the cardiac bronchus usually produces no signs or symptoms but can be associated with cough, recurrent infection, empyema, and hemoptysis [9–11, 14, 15]. A combination of a tracheal bronchus and a cardiac bronchus has been described in the same patient [16].

A bridging bronchus is rare. The bridging bronchus is a bronchus intermedius that arises from the left main bronchus, crosses the midline, and supplies the lower right lung [9, 10].

Bronchial anomalies also occur with abnormalities of situs. In the case of situs inversus, the right and left lungs are switched in positions. In situs ambiguous, left isomerism or right isomerism can be present. In left isomerism, there are bilateral morphologic left lungs and polysplenia. In right isomerism, there are bilateral morphological right lungs, asplenia, and frequently congenital heart disease [9, 17].

Bronchial atresia is most common in the left upper lobe. The cause of bronchial atresia is unknown but may be secondary to ischemic insult or developmental dysfunction. The bronchi distal to the atretic segment are often impacted with mucus. Distal alveoli are aerated via collateral pathways and usually are hyperlucent secondary to air-trapping (Fig. 1.7) [10].

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