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THORACIC IMAGING

PULMONARY AND CARDIOVASCULAR RADIOLOGY

Second Edition

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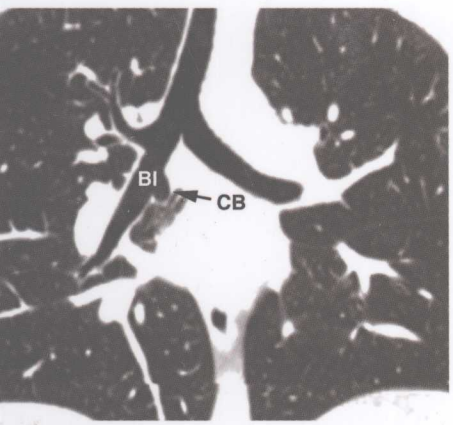
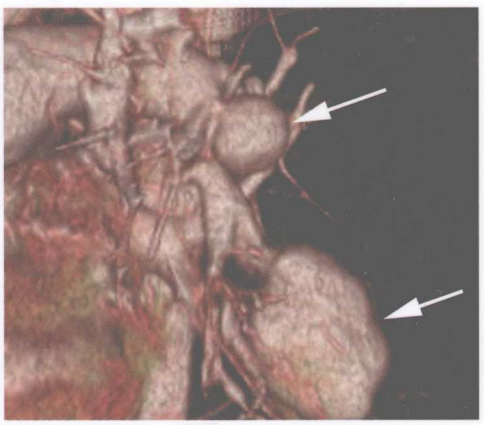
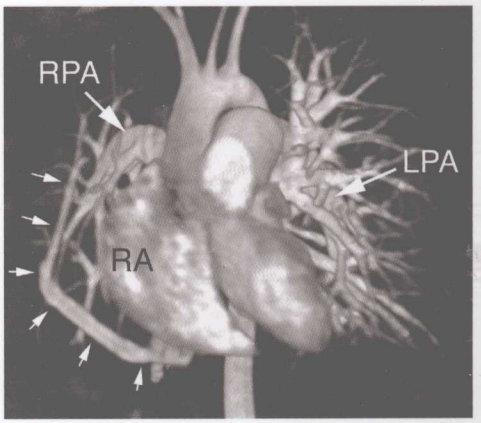
W. Richard Webb • Charles B. Higgins







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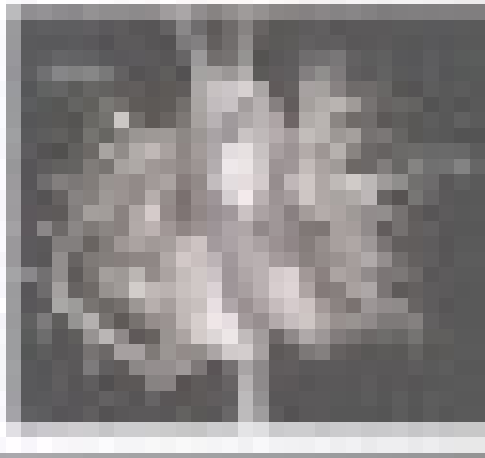

THORACIC IMAGING
Pulmonary and Cardiovascular Radiology

SECOND EDITION

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Pulmonary and Cardiovascular Radiology

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To Jack and Cole, my Grandsons, who learn and teach every day
—W. Richard Webb

To the many fellows who have contributed to our progress
in developing new cardiovascular imaging techniques
—Charles B. Higgins

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PREFACE

Our goal in writing *Thoracic Imaging: Pulmonary and Cardiovascular Radiology* was to provide, in a single volume, a comprehensive but easy-to-digest discussion of the title topic and to review the use and interpretation of chest radiographs and advanced imaging techniques (e.g., spiral computed tomography [CT], high-resolution CT, magnetic resonance imaging [MRI], and magnetic resonance angiography).

We have tried to be thorough without being exhaustive. Rather than referencing specific studies, we have summarized what we consider to be the most important and pertinent information and have provided numerous tables to make key facts easily available to the reader. More than 2,100 illustrations demonstrate important radiographic findings and the typical appearances of the various disease entities one might encounter in current clinical practice. The second edition provides current updates on a number of topics and also provides improved and additional illustrations.

Imaging of the lungs and mediastinum requires an understanding of both plain radiography and CT. Although in many situations CT has assumed a preeminent role, knowledge of chest radiographs and their utility is essential to the radiographic assessment of patients with suspected pulmonary disease. We have attempted to review and illustrate both the plain radiographic and the CT findings of most abnormalities and disorders. Other imaging modalities, such as MRI and radionuclide imaging, are also discussed in situations in which they play a significant role.

Chapters in the pulmonary radiology section of this book are organized according to important radiographic findings, anatomic regions, clinical problems, or disease states, as is appropriate to an approach to diagnosis and differential diagnosis. Radiographic and CT techniques are not described in detail (e.g., there is no chapter specifically on techniques), but these are reviewed in context in various chapters. In most cases, normal radiographic and CT findings are reviewed where appropriate to the understanding of specific abnormal findings or diseases.

Cardiovascular imaging has transitioned nearly completely in the past two decades from dependence on x-ray angiography for definitive diagnosis to noninvasive tomographic imaging techniques. Therefore, *Thoracic Imaging* emphasizes the use of tomographic imaging for the evaluation of cardiovascular morphology and function. The currently employed tomographic techniques are echocardiography, MRI, and CT. Although echocardiography is the most frequently used imaging modality for the evaluation of cardiac disease, it is not included in this volume. Many books encompassing all aspects of echocardiography already exist, so inclusion of it would be not only repetitious but also incomplete because of the intended size of this book. Another practical consideration is that echocardiography is rarely practiced by radiologists.

Frequently, the initial radiographic study used in patients with cardiovascular disease is the thoracic radiograph. Two chapters describe a systematic approach to the evaluation of the thoracic radiograph in acquired and congenital heart disease. The major tomographic imaging technique employed by radiologists in the evaluation of cardiac disease is MRI. The use and interpretation of MRI are described in several chapters covering the various categories of cardiovascular diseases. MRI and CT have become increasingly important in the evaluation of ischemic heart disease in the past few years. Individual chapters describe the current capabilities of MRI and CT in ischemic heart disease.

W. Richard Webb, M.D.
Charles B. Higgins, M.D.

CONTENTS

CHAPTER

1 Congenital Bronchopulmonary Lesions

W. RICHARD WEBB

A variety of congenital abnormalities may involve the bronchi, lung and it vascular supply. They often have characteristic plain film and computed tomography (CT) findings. Congenital abnormalities of the aorta and great vessels are reviewed in Chapter 35.

BRONCHIAL ANOMALIES

Anomalies of bronchial anatomy include abnormal origin, absent branches, supernumerary branches, and congenital diverticula (Table 1-1). Minor variation in subsegmental bronchial anatomy is common but clinically insignificant; a detailed knowledge of subsegmental bronchial anatomy is not necessary for clinical practice. Variation in segmental bronchial anatomy is less frequent and not often of significance.

Tracheal Bronchus

A tracheal bronchus is present in about 0.1% of the population. It usually arises from the right tracheal wall, at or within 2 cm of the tracheal bifurcation. It supplies a variable portion of the medial or apical right upper lobe, most often the apical segment (Fig. 1-1); in occasional cases, the entire right upper lobe bronchus arises from the trachea (Fig. 1-2). When a right-sided tracheal bronchus is present, the azygos arch is seen above the tracheal bronchus. Tracheal bronchus is sometimes referred to as a "pig bronchus" or "bronchus suis" as it is common in pigs and other cloven-hoofed animals.

In most cases, this anomaly is insignificant. However, recurrent infection or bronchiectasis may result, since the tracheal bronchus is often slightly narrowed at its origin. A left tracheal bronchus, supplying the apical posterior segment of the left upper lobe, is rarely present; it is much less common than a right-sided tracheal bronchus. The term "tracheal bronchus" is sometimes used to refer to a displaced bronchus, supplying a part of the upper lobe, even if it does not arise from the trachea.

Accessory Cardiac Bronchus

Accessory cardiac bronchus is a supernumerary bronchus with an incidence of about 0.1%. It arises from the medial wall of the bronchus intermedius or right lower lobe bronchus and extends inferiorly and medially toward the mediastinum or heart. In some cases, the cardiac bronchus is a short, blind-ending bronchial stump without associated alveolar tissue, and it may terminate in the mediastinum. In others, a longer branching bronchus is present, associated with rudimentary lung tissue (Fig. 1-3). In most cases, this anomaly is an incidental finding; occasionally, chronic infection or hemoptysis is associated.

Bronchial Isomerism

Bronchial isomerism refers to bilateral symmetry of the bronchi and associated pulmonary lobes. It may be isolated or associated with a variety of anomalies, particularly congenital heart disease. Bronchial anatomy may be bilaterally right sided (associated with asplenia) or left sided (associated with polysplenia).

TABLE 1.1 Bronchial Anomalies

Variations in subsegmental branching
Common but insignificant
Tracheal bronchus
Incidence 0.1%
Arises from right tracheal wall; rare on left
Usually supplies apical segment of right upper lobe
Rarely supplies entire right upper lobe
Increased incidence of infection or bronchiectasis
Accessory cardiac bronchus
Incidence 0.1%
Arises from medial wall of bronchus intermedius
Usually blind ending or supplies rudimentary lung
May terminate in the mediastinum
Increased incidence of infection or hemoptysis
Bronchial isomerism
Symmetrical bronchial anatomy
Bilateral right- or left-sided bronchial anatomy
Associated with congenital heart disease, other anomalies

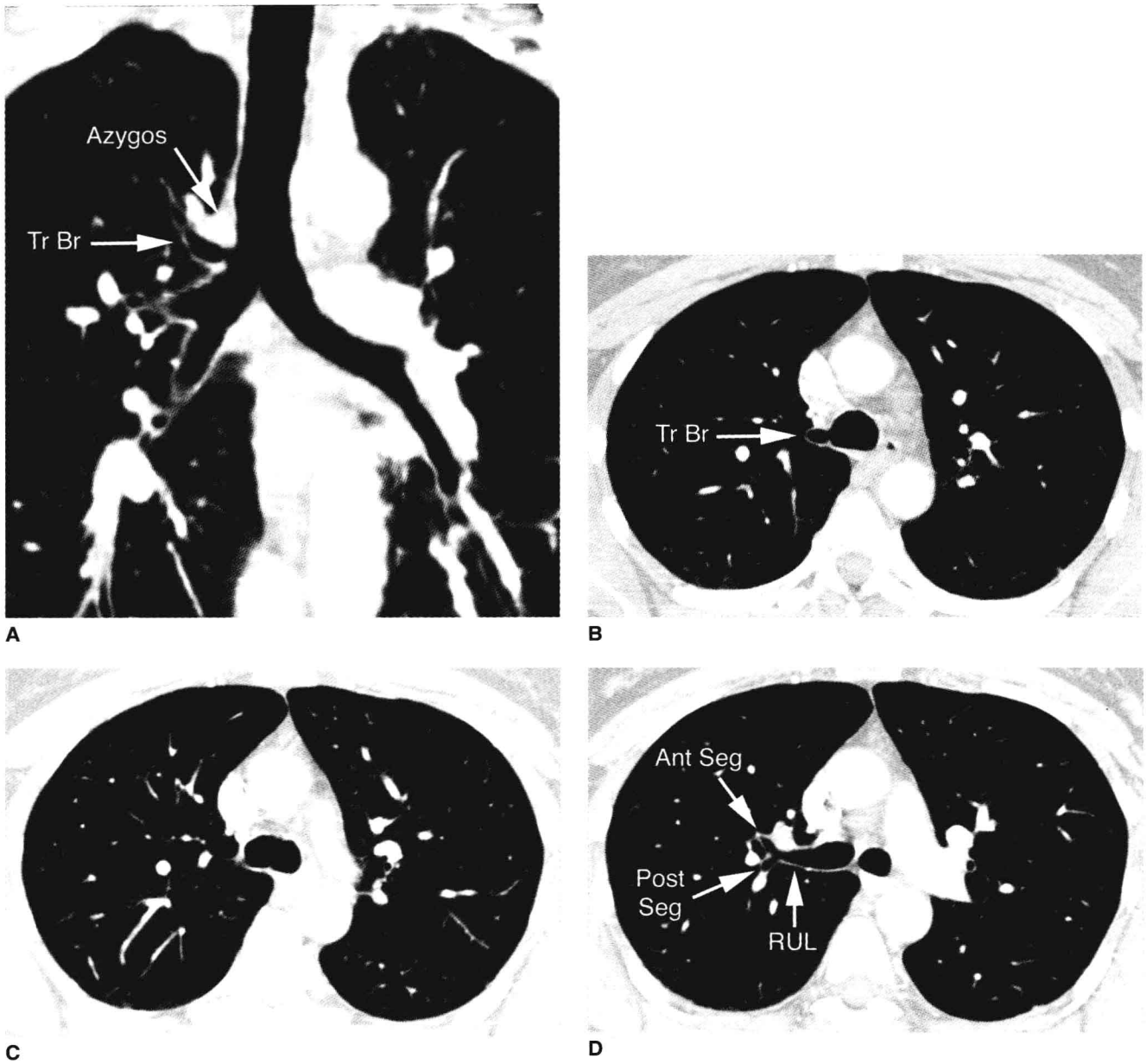


FIG. 1.1. Tracheal bronchus. **A:** Coronal CT reconstruction shows a tracheal bronchus (*Tr Br*) arising from the right tracheal wall just above the carina. The azygos arch (*Azygos*) is visible above the bronchus. **B:** CT (1.25-mm slice thickness) shows the origin of the tracheal bronchus. As in this case, slight narrowing at the origin of the bronchus is common. The bronchus supplies the apical segment of the right upper lobe. **C:** The tracheal carina is seen slightly below (**B**). **D:** Below (**C**), the main right upper lobe bronchus (*RUL*) gives rise to the anterior (*Ant Seg*) and posterior (*Post Seg*) segmental bronchi.

BRONCHIAL ATRESIA

Bronchial atresia is a developmental defect characterized by local narrowing or obliteration of a lobar, segmental, or subsegmental bronchus (Table 1-2). It is most common in the left upper lobe, followed by the right upper and right middle lobes; it is less common in the lower lobes. This entity is usually detected incidentally in adults and is undoubtedly related to congenital lobar emphysema (CLE). Patients usually have no symptoms, but lung distal to the obstruction may occasionally become infected. In patients with chronic infection, resection may be necessary.

The lobe or segment distal to the bronchial obstruction usually remains aerated because of collateral ventilation

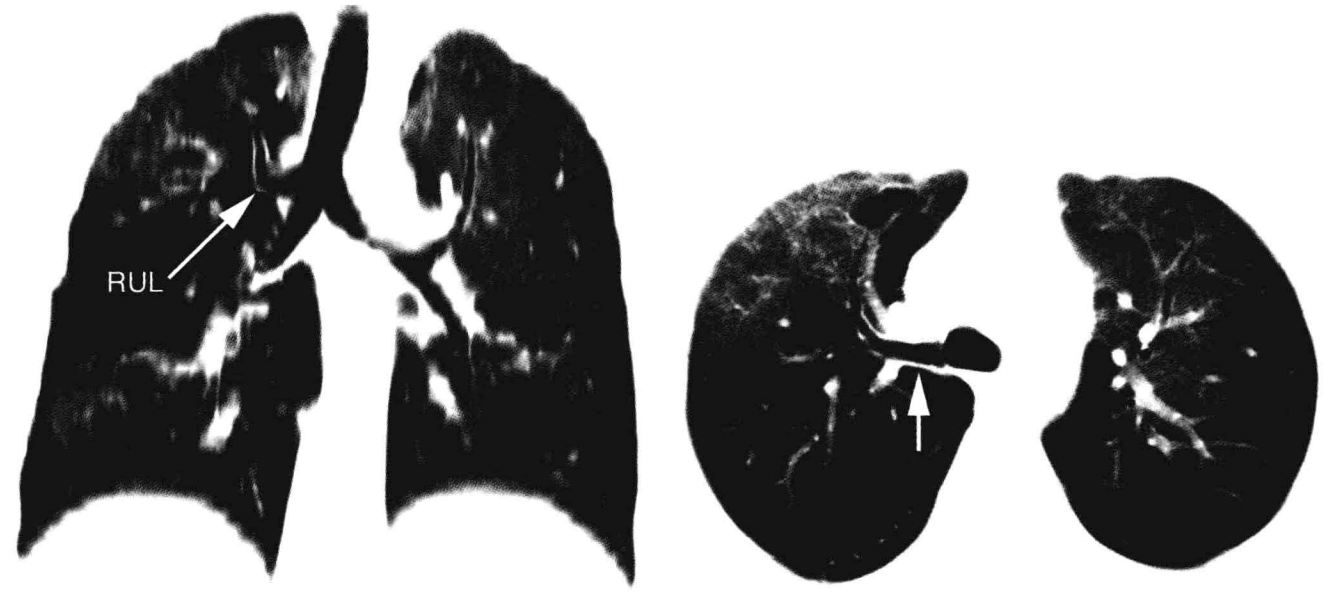


FIG. 1.2. Tracheal bronchus in a patient with pneumonia. **A:** Coronal reconstruction shows the entire right upper lobe bronchus (*RUL*) arising from the right tracheal wall above the carina. The apical segmental bronchus extends superiorly. **B:** Transaxial CT shows the right upper lobe bronchus (*arrow*) giving rise to anterior and posterior segments. Patchy areas of increased lung opacity reflect the presence of pneumonia.

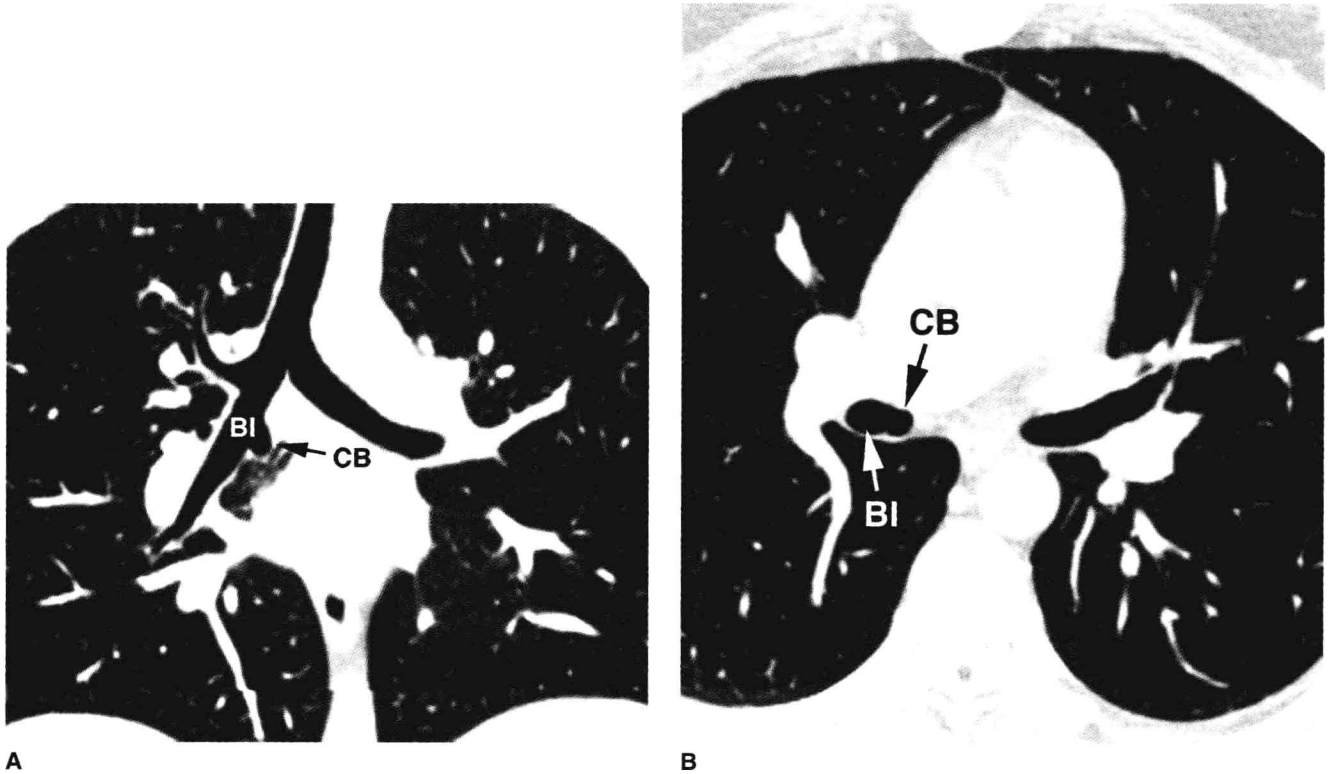
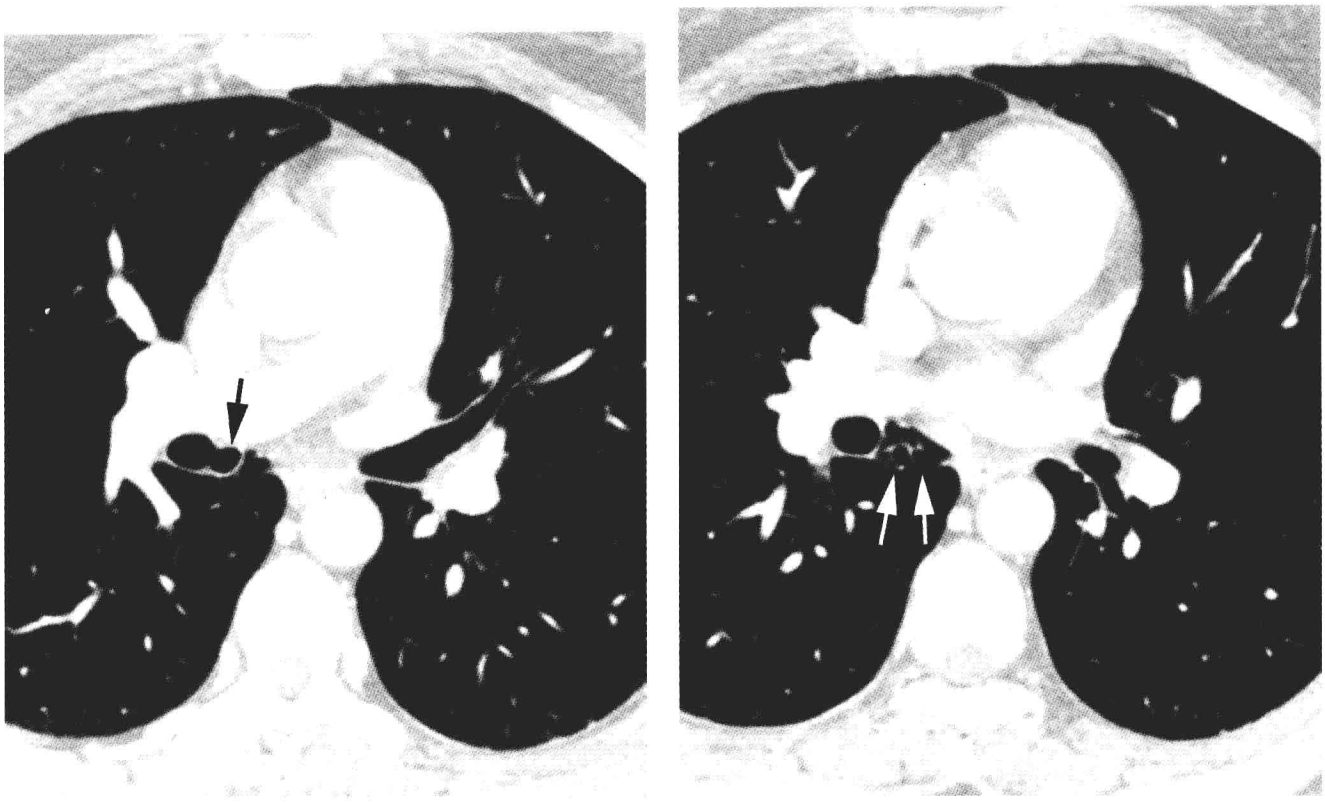


FIG. 1.3. Accessory cardiac bronchus. **A:** Coronal CT reconstruction shows an accessory cardiac bronchus (*CB*) arising from the medial aspect of the bronchus intermedius (*BI*), to supply a small region of lung. **B:** Transaxial image shows the cardiac bronchus (*CB*) arising from the medial wall of the bronchus intermedius (*BI*). (*Figure continues.*)



C D

FIG. 1.3. (*Continued.*) **C:** Slightly below (**B**), the cardiac bronchus (*arrow*) is seen medial to the bronchus intermedius. **D:** Below (**C**), the bronchus supplies a small segment of lung separated from the lower lobe by an accessory fissure (*arrows*).

(Figs. 1-4 and 1-5). In 90% of cases, air trapping in the distal lung results in decreased perfusion; radiographs and CT show the affected lung to be hyperlucent and hypovascular. Affected lung is often increased in volume, resulting in mediastinal shift or shift of a fissure. In 80% of cases, mucus accumulates within dilated bronchi distal to the obstruction, resulting in a tubular, branching, or ovoid density (mucous plug or *mucocele*). Mucus within dilated bronchi usually appears low in attenuation. Expiratory radiographs or CT scans show air trapping (see Fig. 1-5B).

The combination of these typical radiographic or CT findings in a young patient is strongly suggestive of the diagnosis. Bronchoscopy may be warranted to rule out another cause of bronchial obstruction, such as tumor.

TABLE 1.2 Bronchial Atresia

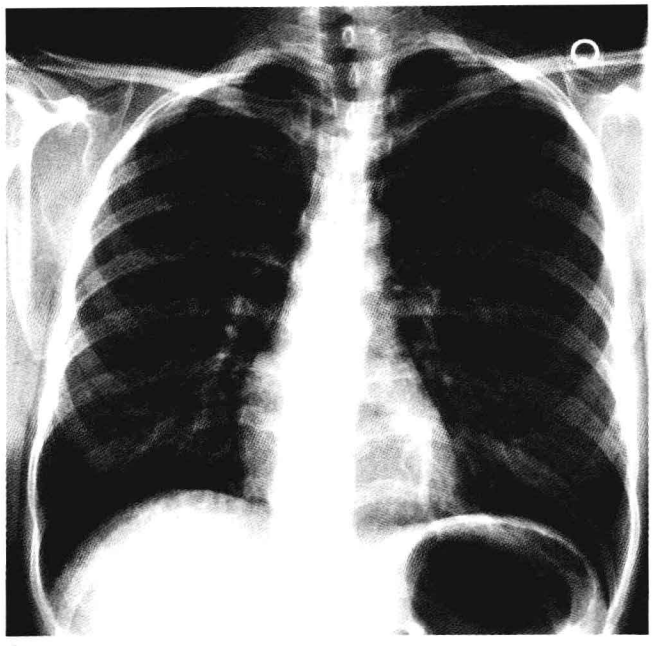
Narrowing or obliteration of a lobar, segmental, or subsegmental bronchus
Left upper lobe > right upper lobe > right middle lobe > lower lobes
Detected incidentally in adults
Infection may occur
Mucous plug distal to obstructed bronchial segment
Distal lung
Lucent
Increased in volume
Decreased vessel size
Air trapping on expiration
Rule out obstructing tumor

CONGENITAL LOBAR EMPHYSEMA

CLE, also known as congenital lobar hyperinflation, is characterized by marked overinflation of a lobe (Table 1-3). Most cases present within the first month of life; symptoms of respiratory distress are typical. Presentation after the first month may occur.

Most cases of CLE are associated with partial or complete bronchial obstruction occurring as a result of (a) deficient cartilage; (b) external compression, usually by an anomalous vessel or bronchogenic cyst; or (c) luminal abnormalities such as mucosal folds. Some cases are unassociated with bronchial obstruction.

CLE is most common in the left upper lobe, followed by the right middle lobe and right upper lobe. Only a few percent



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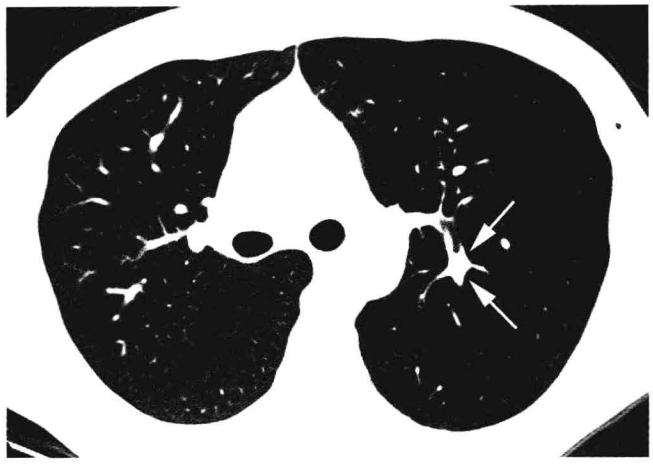

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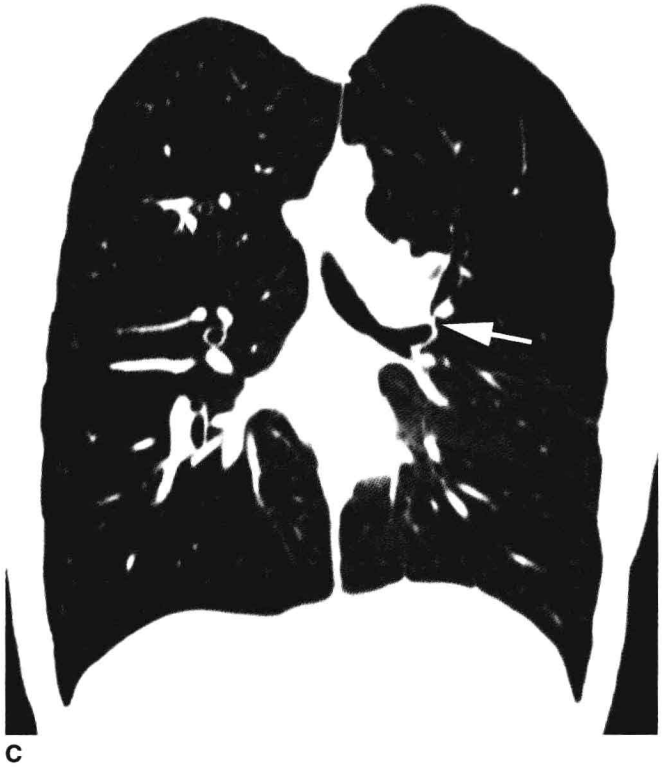

C

FIG. 1.4. Bronchial atresia. **A:** Chest radiograph in a young patient with bronchial atresia involving the left upper lobe. The left upper lobe is increased in volume, with mediastinal shift toward the right side. The lobe is lucent, and its vascularity is decreased. **B:** Transaxial CT shows the left upper lobe to be increased in volume, with mediastinal shift to the right, hyperlucent, and hypovascular. Branches of the left upper lobe bronchus are dilated, and one branch contains a mucous plug (*arrows*). **C:** Coronal reconstruction shows the hyperlucent and hypovascular left upper lobe with focal atresia of its apical-posterior segmental branch (*arrow*). Distal bronchi are dilated.

occur in the lower lobes. Radiographs typically show marked overinflation and air trapping in the affected lobe. However, in neonates, the affected lobe may sometimes appear opaque because of retained fetal lung fluid. Mediastinal shift away from the abnormal lobe often occurs, and normal lobes are reduced in volume. Resection is often necessary.

It is reasonable to assume that cases of CLE that go unrecognized at birth may be diagnosed years later as bronchial atresia.

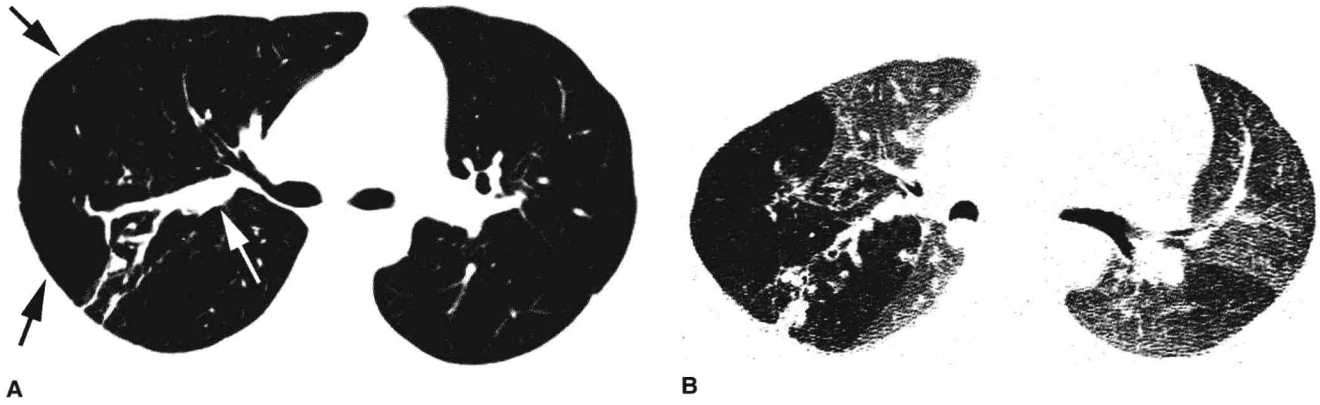

FIG. 1.5. Bronchial atresia. **A:** CT shows a branching mucous plug (*white arrow*) in the location of the posterior segmental bronchus of the right upper lobe. Lung distal to the bronchus (*black arrows*) is hyperlucent and hypovascular. Mediastinal shift to the left side is present. **B:** Expiratory CT shows air trapping in the lung distal to the obstructed bronchus. Normal lung increases significantly in attenuation relative to (**A**).

PULMONARY BRONCHOGENIC CYST

Bronchogenic cysts are foregut duplication cysts and result from abnormal development of the lung bud. They are lined by pseudostratified ciliated columnar epithelium, typical of bronchi. The cyst wall may also contain smooth muscle, mucous glands, or cartilage. Bronchogenic cysts are filled with fluid, which can be serous, hemorrhagic, or highly viscous and gelatinous because of its high protein content.

Bronchogenic cysts may be mediastinal or pulmonary. Mediastinal bronchogenic cysts are much more common than pulmonary cysts. They are discussed along with mediastinal masses in Chapter 8.

Pulmonary bronchogenic cysts are most common in the medial lung and the lower lobes (Table 1-4). They are sharply circumscribed and round or oval. The cyst wall may calcify. Rarely, the cyst may contain milk of calcium and appear dense. Cysts may slowly increase in size; a rapid increase in size is unusual unless infection occurs.

About half of fluid-filled bronchogenic cysts appear to be low in attenuation on CT (0 to 20 HU) (Fig. 1-6). However, as with mediastinal bronchogenic cysts, the CT attenuation of a pulmonary bronchogenic cyst is variable. High CT numbers (40 to 80 HU), suggesting a solid mass, can be seen. Such cysts contain bloody or thick, proteinaceous fluid. Typically, the cyst wall appears very thin on CT or is invisible. A bronchogenic cyst may sometimes appear to be related to a small bronchus.

Infection eventually occurs in 75% of cases. In the presence of acute infection, a rapid increase in size of the cyst may be seen. Also, the outer cyst wall may become less well defined because of surrounding lung inflammation. During or after infection, a cyst may contain air (Fig. 1-7; see also Fig. 9-29 in Chapter 9) or a combination of air and fluid (with an air-fluid level). When the cyst contains air, its wall appears very thin.

TABLE 1.3 Congenital Lobar Emphysema

- Partial or complete bronchial obstruction caused by:
  - Deficient cartilage
  - External compression
  - Luminal abnormalities
- Some cases unassociated with bronchial obstruction
- Left upper lobe > right middle lobe > right upper lobe > lower lobes
- Respiratory distress in neonates
- Presentation after first month uncommon
- Marked overinflation of lobe
- Air trapping
- Sometimes the abnormal lobe retains fetal lung fluid
- Resection often necessary

TABLE 1.4 Pulmonary Bronchogenic Cyst

- Foregut duplication cyst
- Lined by bronchial epithelium
- Fluid contents can be serous, hemorrhagic, or viscous
- Less common than mediastinal bronchogenic cyst
- Most common in medial lung and lower lobes
- Sharply circumscribed and round or oval
- Thin wall; occasionally calcifies
- Contents 0–20 HU in half; often 40–80 HU; milk of calcium rare
- Infection occurs in 75%
  - Rapid increase in size
  - Blurring of outer edge
  - Air-fluid level
  - Air in cyst may remain after infection

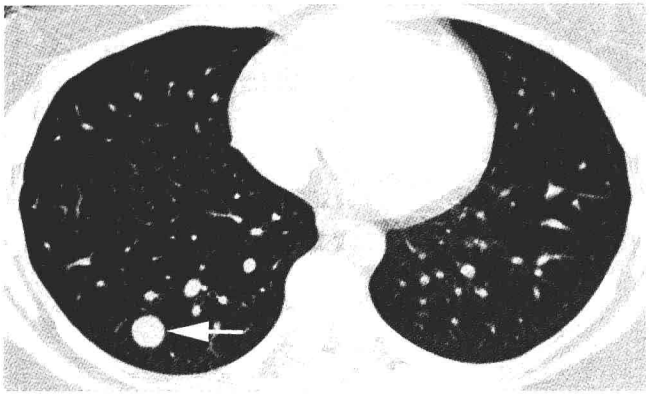

FIG. 1.6. Pulmonary bronchogenic cyst. A sharply marginated round nodular opacity (*arrow*) is visible in the right lower lobe. This measured 0 HU in attenuation. This appearance is typical of a fluid-filled bronchogenic cyst.

CONGENITAL CYSTIC ADENOMATOID MALFORMATION (CONGENITAL PULMONARY AIRWAY MALFORMATION)

Congenital cystic adenomatoid malformation (CCAM), also termed congenital pulmonary airway malformation (CPAM) consists of a multicystic, intralobar mass of disorganized lung tissue, derived primarily from bronchioles. About 70% present during the first week of life, but 10% are diagnosed after the first year, and rare cases in adults have been reported.

CCAM/CPAM can involve an entire lobe. Lower lobes are most often involved, but any lobe can be affected. The CCAM/CPAM communicates with the bronchial tree and is supplied by the pulmonary artery; systemic arterial supply is rarely present.

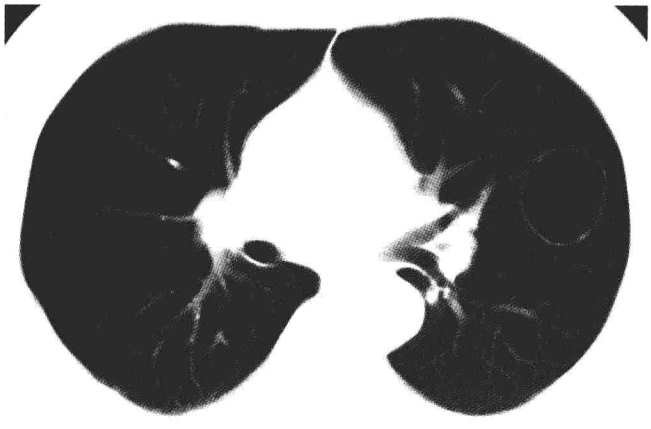

FIG. 1.7. Pulmonary bronchogenic cyst. A thin-walled, sharply marginated, air-filled bronchogenic cyst is visible in the left lung. The presence of air within the cyst indicates prior infection.

TABLE 1.5 Congenital Cystic Adenomatoid Malformation (CCAM)

Also known as Congenital Pulmonary Airway Malformation (CPAM)
Multicystic, intralobar mass of disorganized lung tissue
70% present in first week; 10% after first year
Respiratory distress in neonates; recurrent infection in adults
Most common in lower lobe
Three primary types
Type 1 (65%)
One or more cysts, >2 cm in diameter
May appear initially as solid mass
Large air-filled multicystic lesion
Sometimes with air fluid levels
May occupy the entire hemithorax
Type 2 (20%–25%)
Multiple cysts <2 cm in diameter
May appear initially as solid mass
Air-filled multicystic mass or focal consolidation
Associated renal and cardiac abnormalities
Often a poor prognosis
Type 3 (10%)
Microscopic (<3–5 mm) cysts
Appears as solid mass
Two additional types proposed, based on histology, each a few percent of cases
Type 0
Small cysts
Similar to Type 3 in appearance
Type 4
Large cysts
Similar to Types 1 and 2 in appearance

CCAMs are typically classified into three primary types (Types 1 to 3), which have different histology, gross pathologic findings, radiographic appearance, and prognosis (Table 1-5).

Type 1 CCAMs (65% of cases) contain one or more cysts more than 2 cm in diameter (Fig. 1-8). They usually appear radiographically as a large, air-filled multicystic lesion, sometimes with air-fluid levels, which may occupy the entire hemithorax.

Type 2 CCAMs (20% to 25% of cases) contain multiple cysts less than 2 cm in diameter. They present radiographically as an air-filled multicystic mass or a solid mass or area of consolidation (see Fig. 1-9). This type may be associated with a poor prognosis because of associated renal and cardiac abnormalities.

Type 3 CCAMs (10% of cases) contain microscopic (less than 3 to 5 mm) cysts and present radiographically as a solid mass.

Two additional types of CCAM have been proposed, Types 0 and 4, based on histopathologic findings and the type of airway epithelium involved in the malformation. The term CPAM (congenital pulmonary airway malformation) has been suggested to encompass this expanded classification. Types 0 and 4 CCAM/CPAM each account for a few percent of cases. Type 0 CCAM/CPAM is associated with small cysts,