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28

Bronchiectasis

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Bronchiectasis was a common disease when tuberculosis and the exanthemata of childhood were rife. Improved health measures and the introduction of antibiotics in the late 1940s resulted in a substantial reduction of these cases. As bronchography became an outmoded diagnostic procedure, lesser degrees or forms of bronchiectasis were probably overlooked; this also contributed to the perceived rarity of the disease.

Increasing numbers of patients with bronchiectasis are being noted for several reasons. One is the frequent use of computed tomography (CT) that allows direct visualization of bronchiectasis, obviating the need for bronchography. Another is the recognition of several genetic and congenital disorders that produce bronchiectasis as a main clinical manifestation. The emergence of tuberculosis and other infections among immunosuppressed and AIDS victims is probably another contributing factor. In lung transplant patients, bronchiectasis may become a serious problem (see Chap. 71). There could be yet another element, derived from the emphasis on inflammation and infection as treatable causes of chronic bronchitis, which has led some investigators to use the term "bronchiectasis" to signify chronic production of purulent sputum.[1]

DEFINITION

Strictly used, bronchiectasis means dilatation of airways; it is not a specific disease but rather a complication of many other diseases. The typical patient with bronchiectasis produces a large amount of purulent sputum; understandably, the disease was once a socially disabling condition. To indicate the seriousness of the condition and to exclude minor dilatation of the airways from the diagnosis, some definitions have emphasized that the damage to airway walls must be irreversible. However, because there is also a reversible variety of bronchiectasis, this does not seem to be a satisfactory definition.

In severe bronchiectasis associated with irreversible structural damage, the dilatation of bronchi is accompanied by distal stenosis with obliteration of the bronchial lumen. Although dilatation may be the most obvious and striking feature, it is the presence of stenosis and obliteration of the airway that is most critical for lung function.

In 1923, Sicard and Forestier introduced the use of a radiopaque iodized oil for intraairway administration to outline the bronchial tree (Fig. 28-1).[2] In bronchiectasis, the procedure showed dilatation of airways but, more important, indicated a failure of peripheral filling, pointing toward obstruction of some sort. This absence of peripheral filling is probably functionally more important than the dilatation, but it is too often ignored.

A congenital form of bronchiectasis known as Williams-Campbell syndrome has been described,[3] but the current evidence favors an acquired postnatal condition. The distorted bronchi seen in patients who have had infection in childhood, even if mild, including bronchitis obliterans, are certainly not congenital. The regions of lung affected in this way do not grow normally, so a critical factor in interpreting bronchiectasis is to make allowance not only for airway distortion caused by the original injury but for the subsequent disturbance of lung growth and development. If growth is impaired, numbers of airways, airway size, cartilage size, and histologic features will also be abnormal.

CLASSIFICATION

Clinical Symptoms

Clinicians typically qualify bronchiectasis as either wet or dry, depending on the symptoms. In the wet variety, the chronic production of sputum is striking, and the finding of associated airway distortion is usually severe. In the dry variety, a most common presenting symptom is hemoptysis, probably reflecting increased bronchial artery circulation.

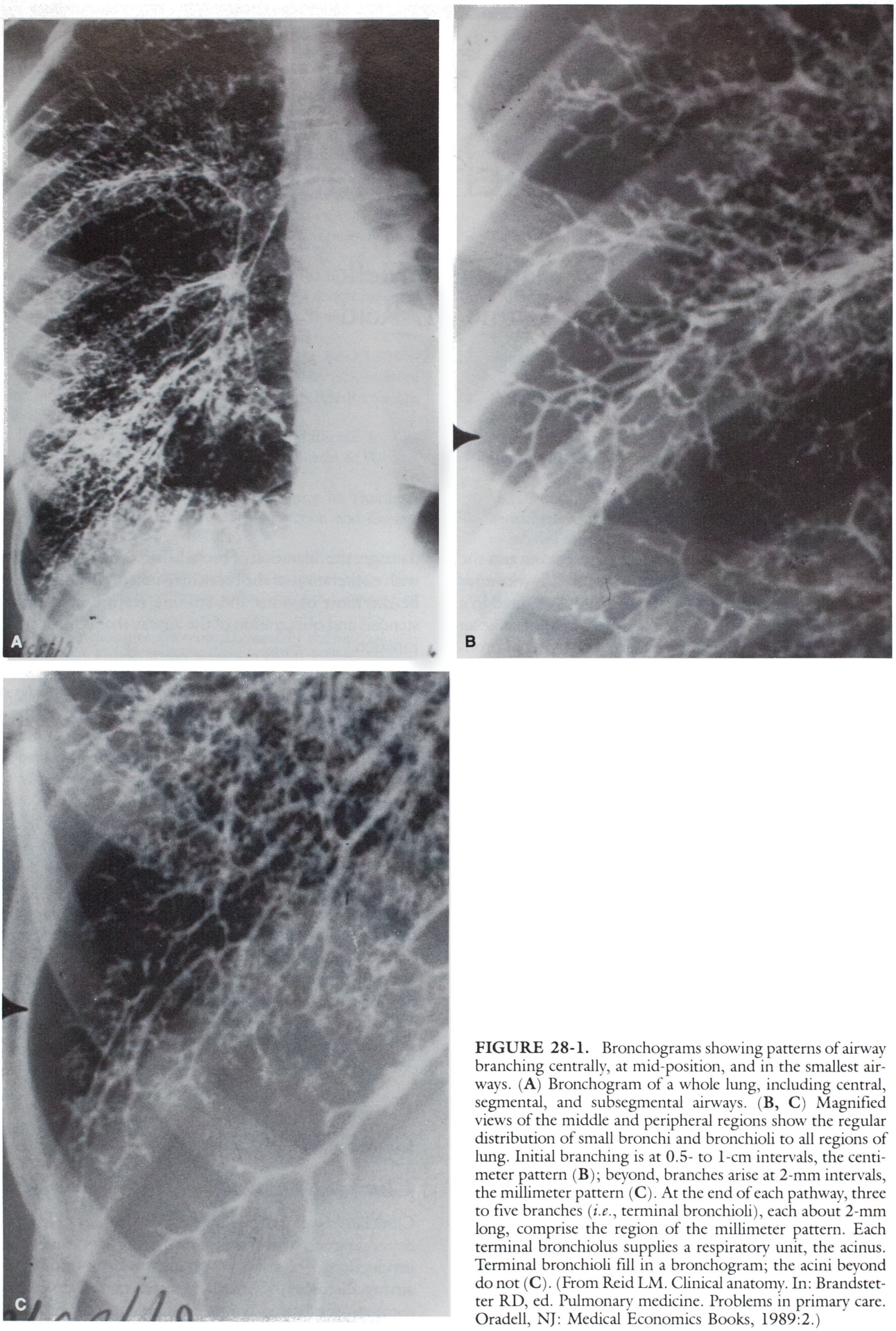


FIGURE 28-1. Bronchograms showing patterns of airway branching centrally, at mid-position, and in the smallest airways. (**A**) Bronchogram of a whole lung, including central, segmental, and subsegmental airways. (**B, C**) Magnified views of the middle and peripheral regions show the regular distribution of small bronchi and bronchioli to all regions of lung. Initial branching is at 0.5- to 1-cm intervals, the centimeter pattern (**B**); beyond, branches arise at 2-mm intervals, the millimeter pattern (**C**). At the end of each pathway, three to five branches (*i.e.*, terminal bronchioli), each about 2-mm long, comprise the region of the millimeter pattern. Each terminal bronchiolus supplies a respiratory unit, the acinus. Terminal bronchioli fill in a bronchogram; the acini beyond do not (**C**). (From Reid LM. Clinical anatomy. In: Brandstetter RD, ed. Pulmonary medicine. Problems in primary care. Oradell, NJ: Medical Economics Books, 1989:2.)

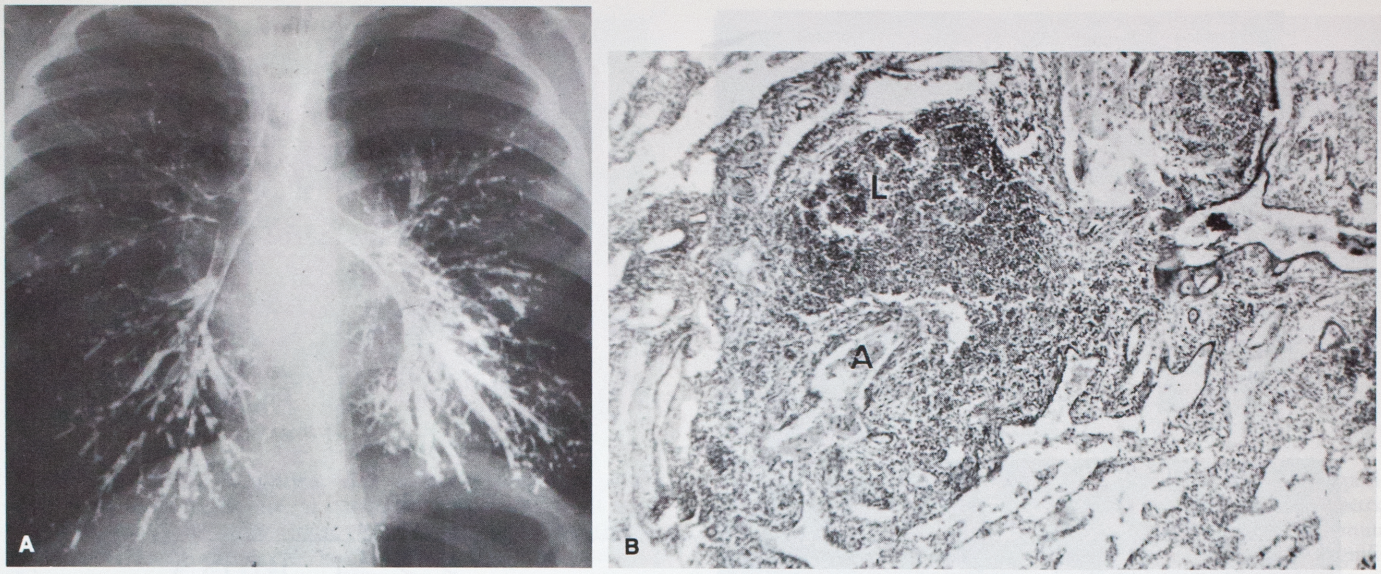


FIGURE 28-2. Cylindrical bronchiectasis. (**A**) A bronchogram of a child with chronic bronchiolitis shows nonfilling of small peripheral airways. (**B**) On microscopic section of the lung, the reason for nonfilling of peripheral airways is the distortion produced by lymphocytic follicular bronchiolitis (L). (H & E stain, low magnification; from Reid LM. The pathology of obstructive and inflammatory airway disease. Eur J Respir Dis 1986;69 [Suppl 147]:26.)

Shape of the Dilated Bronchi

Bronchiectasis can be described as cylindrical, saccular, or varicose.[4] Cylindrical bronchiectasis is a mild, diffuse, and rather uniform dilatation of the airways (Fig. 28-2). Typically, this is not associated with much severe damage to the airways, as in the other types. The saccular or cystic variety describes localized expansion in an airway with a diameter considerably larger than that of the normal airway at this level and even larger than that of the more proximal stretches of such airway (Fig. 28-3). It resembles a cyst because the dilation or expansion of the airway tends to be spherical. Such a region can be single, but quite often it is multiple.

Varicose bronchiectasis has an irregular outline with a corrugated wall representing successive regions of dilatation and narrowing (Fig. 28-4). Where the wall is intact but corrugated in outline, muscle can be seen at the apex of the folds. In the more severe examples, the narrowings represent sites of stenosis and fibrosis. Such changes are largely irreversible (Fig. 28-5).

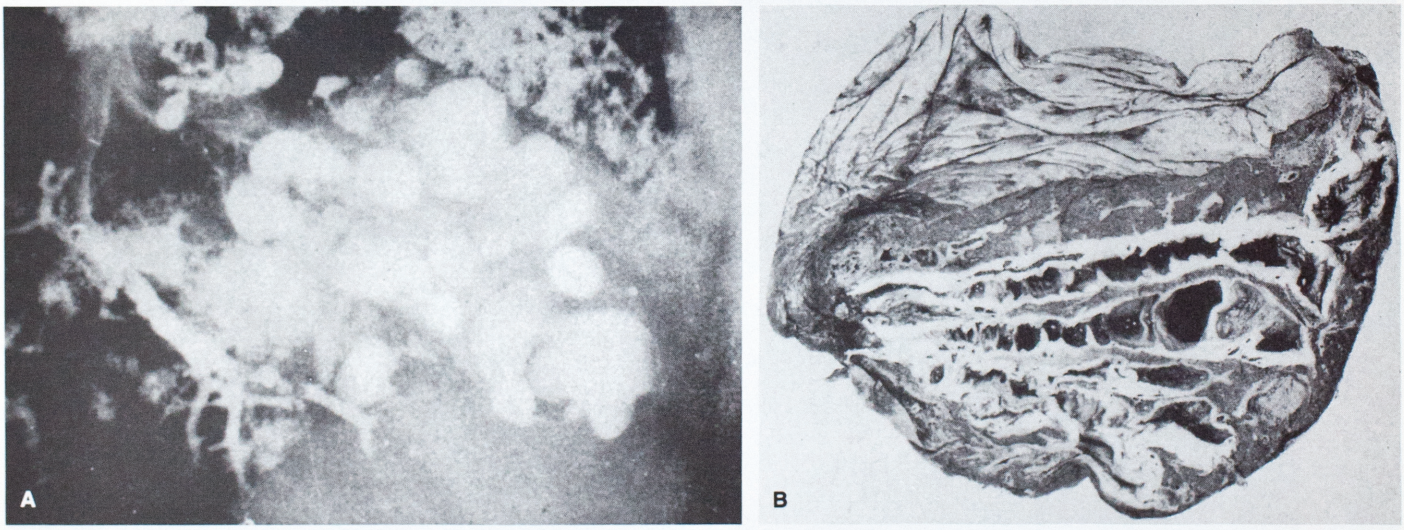
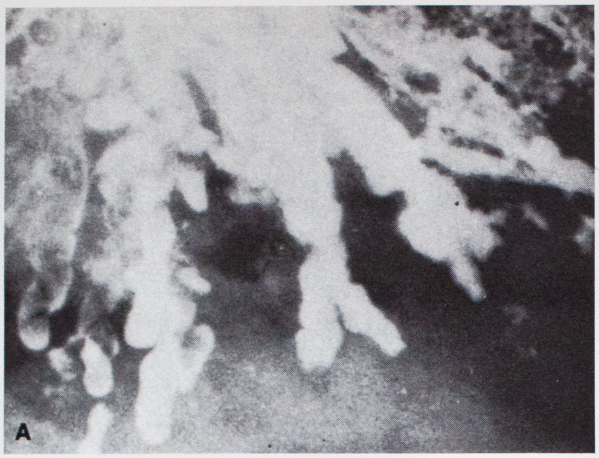
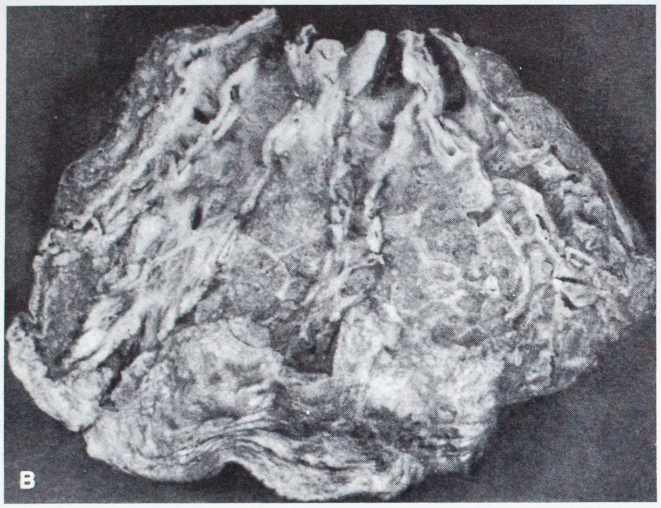
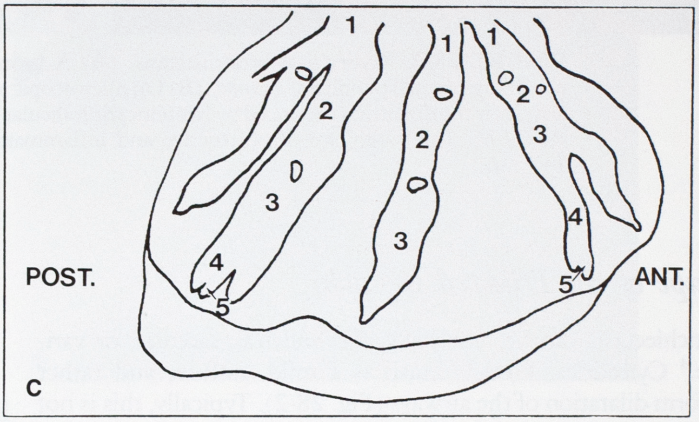
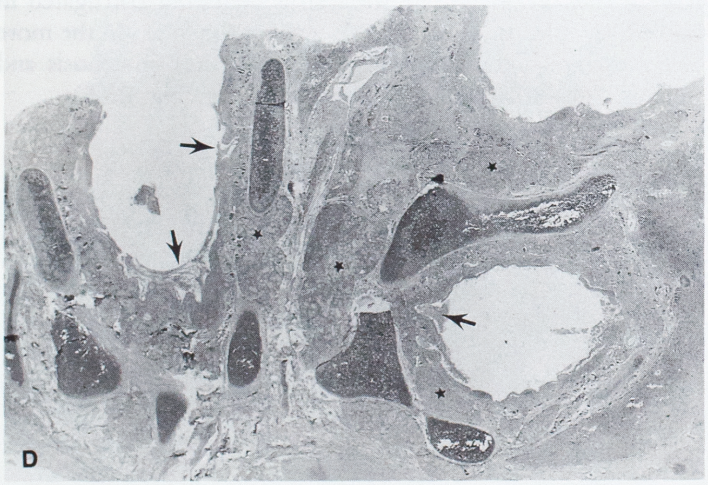


FIGURE 28-3. Saccular bronchiectasis. (**A**) A bronchogram of the right middle lobe shows loculi of contrast medium with no obvious continuity. (**B**) A slice of the resected right middle lobe seen in (**A**) shows an increase in bronchial diameter from hilum to periphery. The terminal portion represents only the fourth bronchial generation from the hilum. The saccule represents ulceration of a large amount of airless collapsed lung. The intrabronchial valvelike folds explain the loculated appearance on bronchogram. (From Reid L. Reduction in bronchial subdivision in bronchiectasis. Thorax 1950;5:233.)









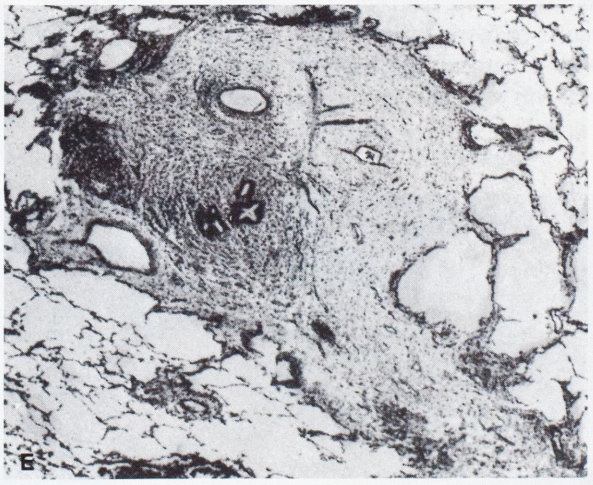
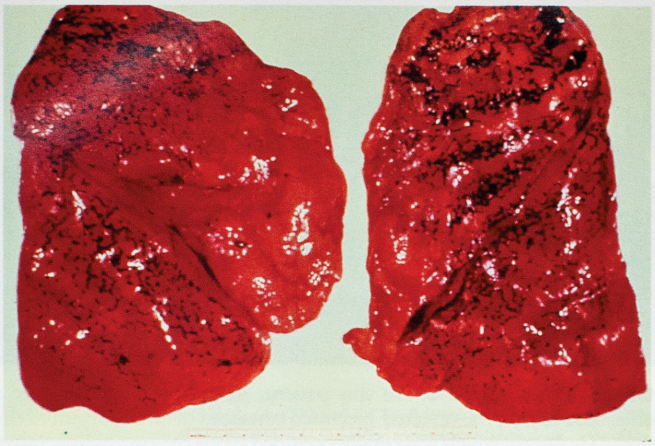
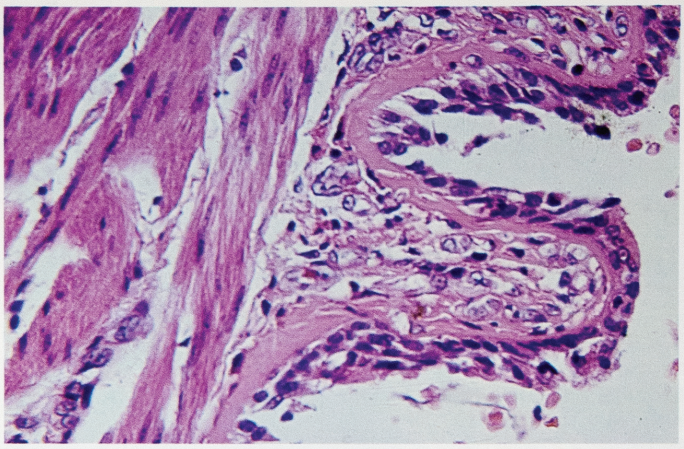


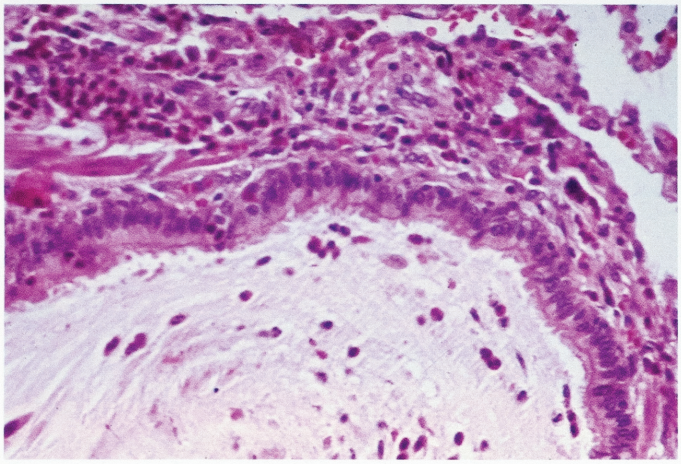
FIGURE 28-4. Varicose bronchiectasis. (**A**) In a bronchogram of the left lower lung, anteroposterior view, the bronchial outline is irregular, and terminations are rounded. (**B**) In the resected left lower lobe shown in (**A**), the anterior, middle, and posterior basal bronchi are open and terminate beneath the pleura; aerated lung is seen between the bronchi. (**C**) The specimen in (**B**) had up to 5 branches in the anterior, middle, and posterior basal bronchi. (**D**) Dilated bronchi in cross section show epithelial ulceration and extension of inflammation into the bronchial wall (*arrows*). Marked mucous gland hypertrophy (★) is also present. (**E**) Continuation of the posterior basal bronchus in microscopic section reveals several small epithelium-lined channels within fibrous tissue. Smooth muscle fibers and elastic tissue were also demonstrated by special stains. (H & E stain, low magnifications.) (From Reid L. Reduction in bronchial subdivision in bronchiectasis. Thorax 1950;5:233.)



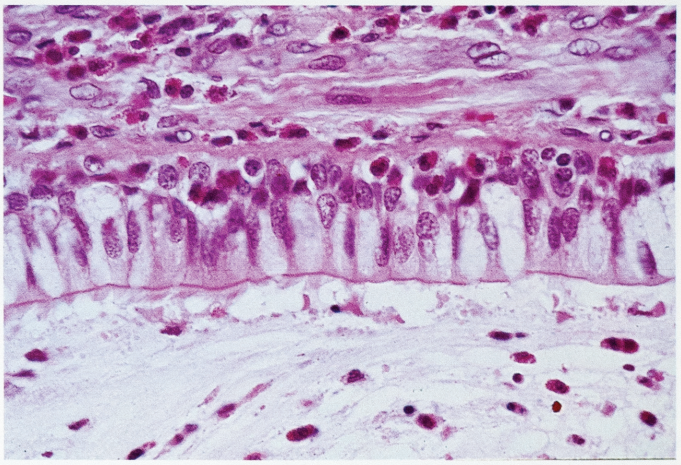
COLOR FIGURE 17-1. Lung specimens from a middle-aged patient who died in status asthmaticus. At postmortem examination, the lungs were hyperinflated and filled the entire pleural cavity; they remained in the same state for 3 hours after extraction from the chest cavity. (Courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



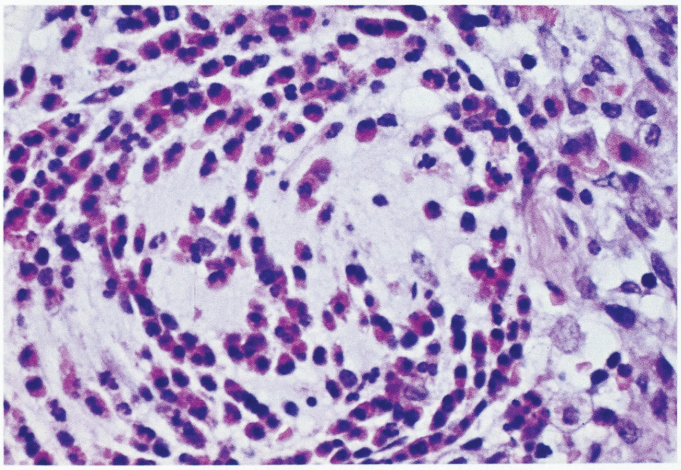
COLOR FIGURE 17-2. A microscopic view of bronchus in the specimen shown in Color Figure 17-1 shows hypertrophic and contracted smooth muscle producing infolding of the mucosa. The basal lamina appears thickened and eosinophilic. (H & E stain; intermediate magnification; courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



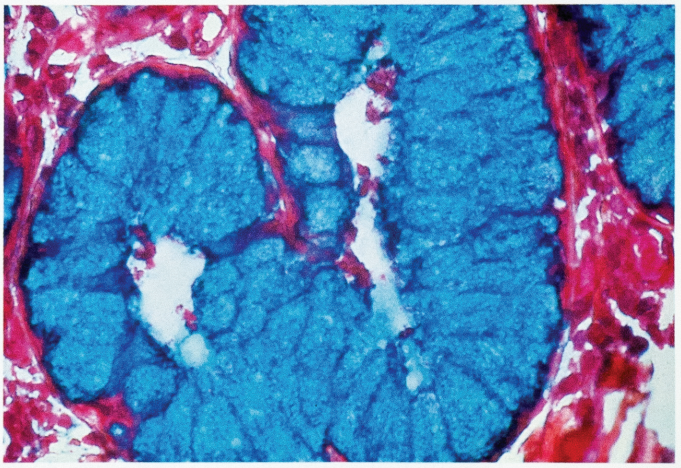
COLOR FIGURE 17-3. The wall of this bronchiole is heavily infiltrated by eosinophils, the lumen is totally occluded by mucus. (H & E stain; low magnification; courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



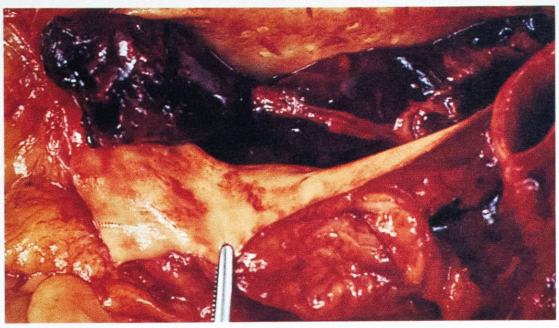
COLOR FIGURE 17-4. Dense eosinophilic infiltrate of the bronchial mucosa and submucosa is present. The luminal mucus also contains numerous eosinophils. There is severe mucinous metaplasia of the airway mucosa. (H & E stain; intermediate magnification; courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



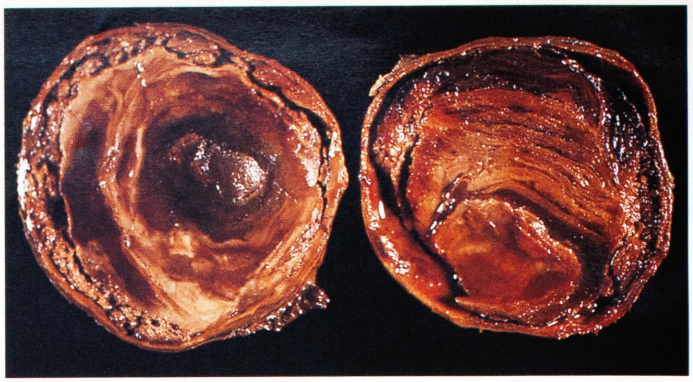
COLOR FIGURE 17-5. A histologic section of a bronchial mucus plug in an asthmatic patient shows large numbers of suspended eosinophils. (H & E stain; intermediate magnification.)



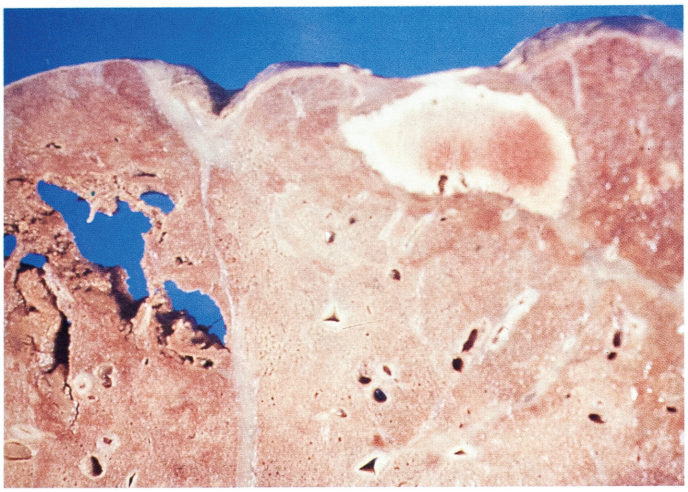
COLOR FIGURE 17-6. In this chronic asthmatic patient, a remarkable mucinous metaplasia of the bronchial glands was found. (Alcian blue stain; intermediate magnification; courtesy of George T. Hensley, M.D., Miami, FL.)



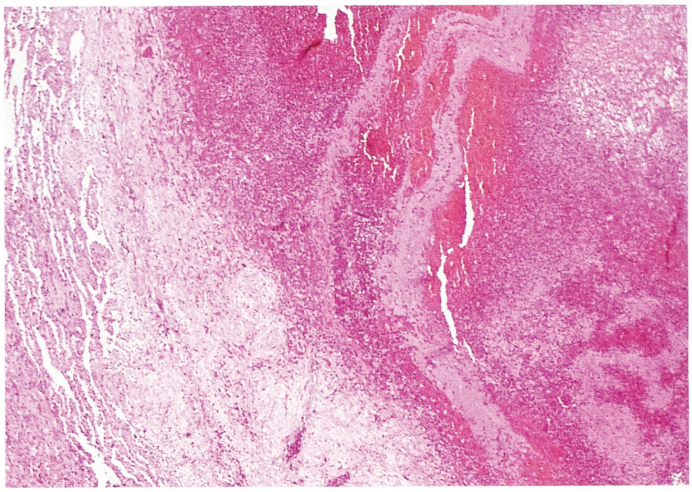
COLOR FIGURE 18-1. A saddle embolus at the bifurcation of the main pulmonary artery.



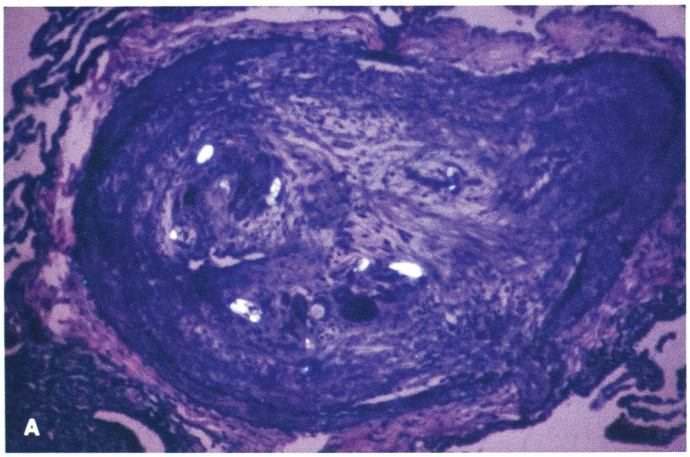
COLOR FIGURE 18-2. In this patient, initially thought to have a mediastinal tumor, the resected specimen consisted of an aneurysm of the pulmonary artery, which was totally occluded by an organizing thrombus showing characteristic laminations known as lines of Zahn (see Fig. 18-3). (Contributed by the editor.)

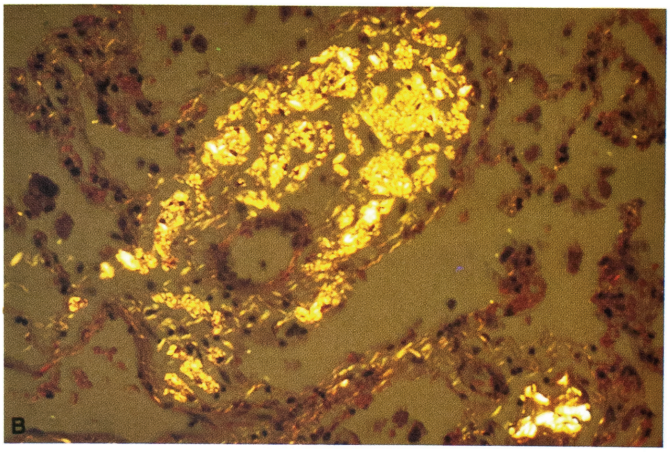


COLOR FIGURE 18-3. Bland, infected lung infarcts with cavitation caused by *Staphylococcus aureus* tricuspid valvulitis in a drug addict. (Contributed by the editor.)

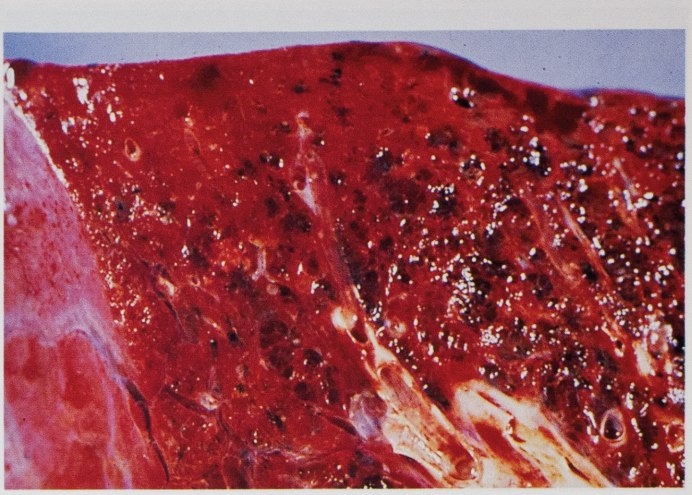


COLOR FIGURE 19-1. A 4-cm, 14-day old pulmonary hematoma was produced by an attempted fine needle aspiration of a peripheral lesion that was retrospectively interpreted as a pseudotumor of the pleura. A fibrin and red cell coagulum is surrounded by a fibrous capsule and atelectatic lung tissue (see Fig. 19-2). (H & E stain; low magnification.)

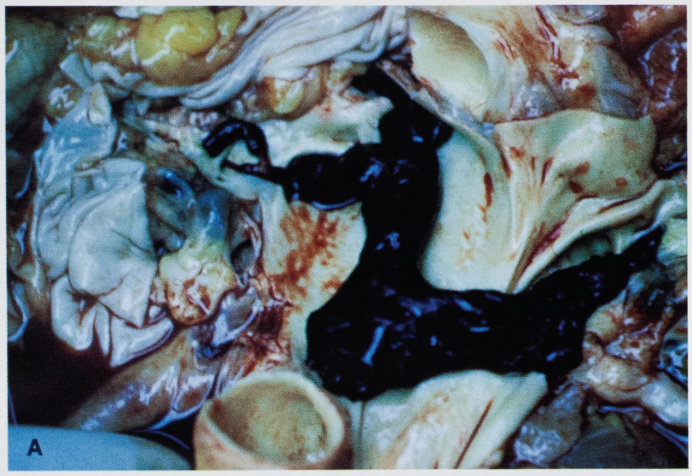


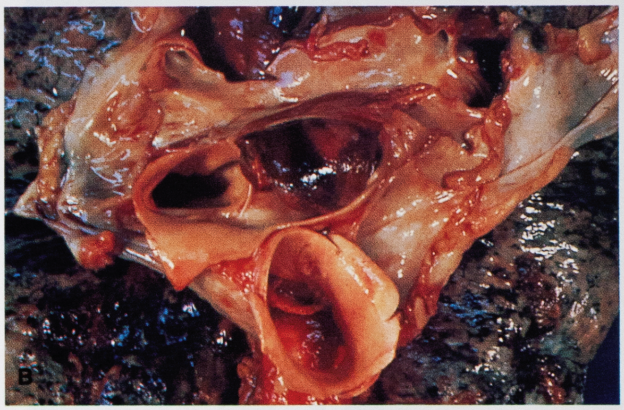


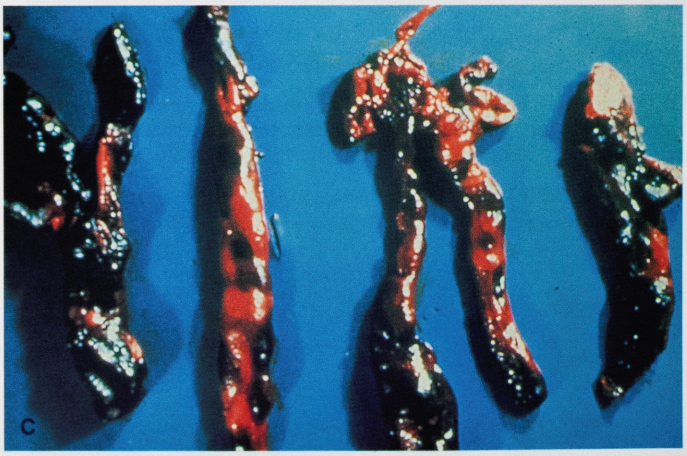
COLOR FIGURE 19-2. (**A**) A medium-sized pulmonary artery in an intravenous drug abuser is totally occluded by fibrosis containing talc crystals, which are best demonstrated by polarized light. (Elastic tissue stain under polarized light; intermediate magnification.) (**B**) The lung of another chronic intravenous drug abuser shows extensive deposits of talc in the pulmonary interstitium (see Fig. 19-9). (H & E stain under polarized light; intermediate magnification.)



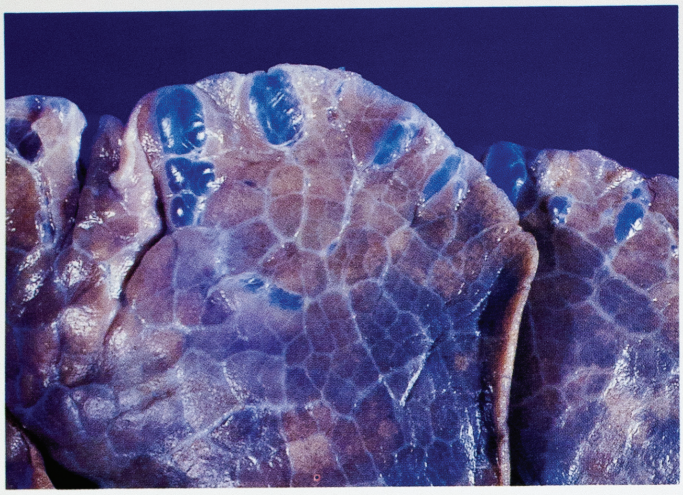
COLOR FIGURE 19-3. Consolidation of lung parenchyma occurred in a man who ingested paraquat for suicidal purposes (see Fig. 19-10). The punch-out spaces represent preexisting emphysema.



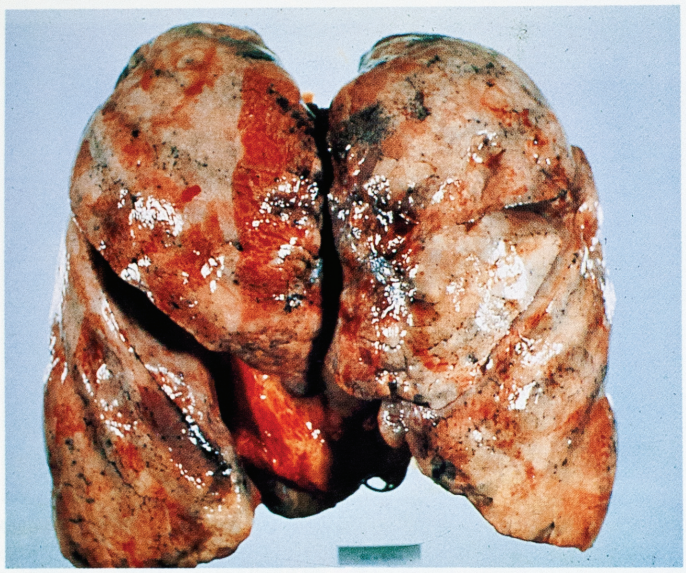




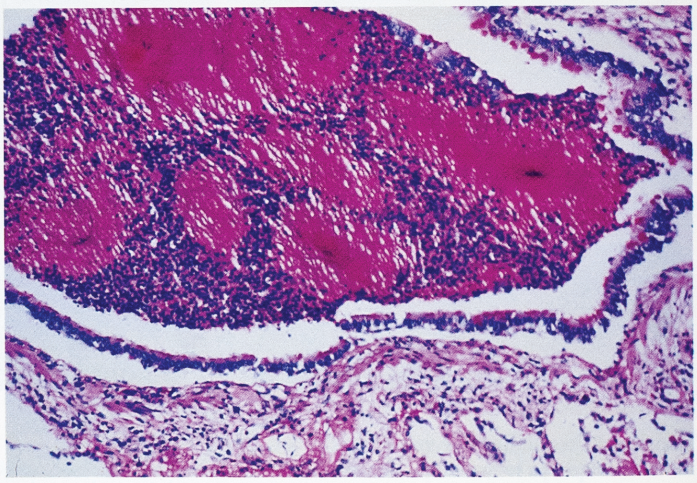
COLOR FIGURE 19-4. Acute pulmonary thromboembolism (see Fig. 19-11). (**A**) A postmortem clot simulates a saddle embolus of the main pulmonary arteries. The clot is rubbery, soft, deep red, and structureless, and it fits snugly within the pulmonary arteries; it should not be misinterpreted as pulmonary embolus. (**B**) A fatal case of acute, unilateral thromboembolus producing obstruction of the left main pulmonary artery. (**C**) Several organizing thromboemboli were extracted from the large veins of the leg of a patient with a history of pulmonary thromboemboli.



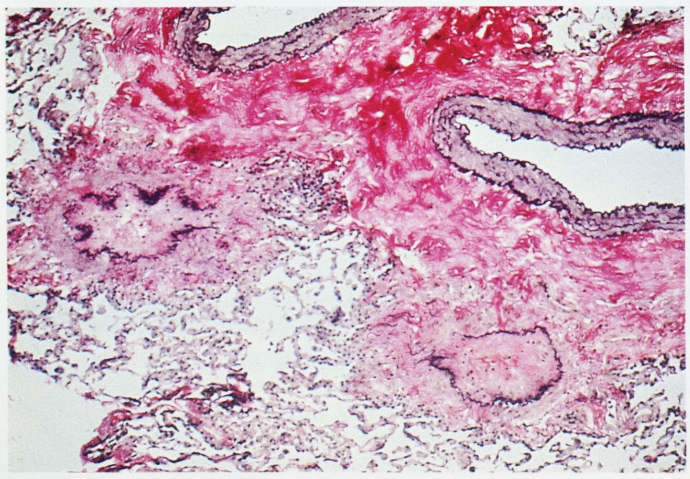
COLOR FIGURE 26-1. A lung specimen from a 23-year-old woman with respirator-induced barotrauma. Blebs in the subpleural space and interlobular septa are characteristic of interstitial emphysema. (Contributed by the editor.)



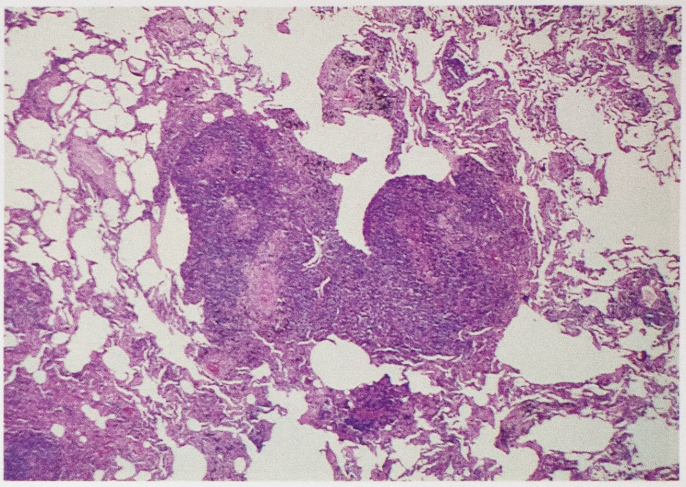
COLOR FIGURE 29-1. The lungs of a middle-aged woman who died of *status asthmaticus* filled the chest cavity but were of normal weight. They remained inflated after extraction from the chest cavity. (Contributed by the editor.)



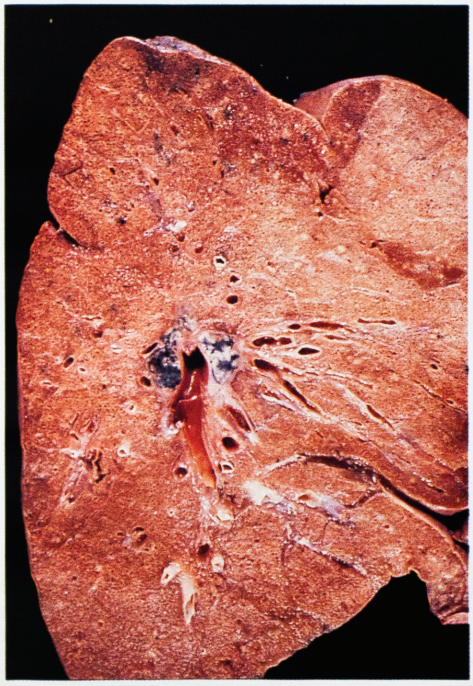
COLOR FIGURE 29-2. Autopsy specimen showing a bronchiole from a long-term cotton worker with a history of byssinosis, who died of an unrelated cause. The epithelium is intact but consists mainly of mucus-secreting goblet cells. The lumen is plugged with mucus and inflammatory cells, and there is chronic inflammation in the wall. Not all bronchioles were involved to this degree. (PAS stain; low magnification.)



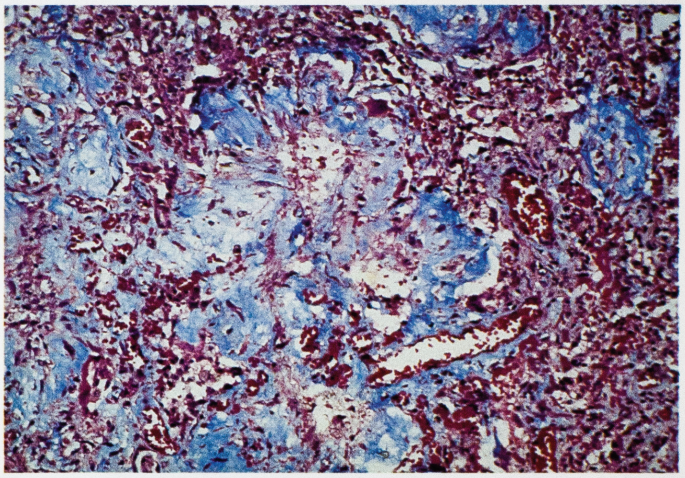
COLOR FIGURE 30-1. End-stage bronchiolitis and peribronchiolitis with total occlusion by dense fibrous connective tissue. The outline of the bronchiolar wall is stained black; the connective tissue is bright red. The accompanying pulmonary arteries show medial hypertrophy. The patient had no significant emphysema nor chronic bronchitis. (Elastic tissue and van Gieson stains; panoramic view; contributed by the editor.)



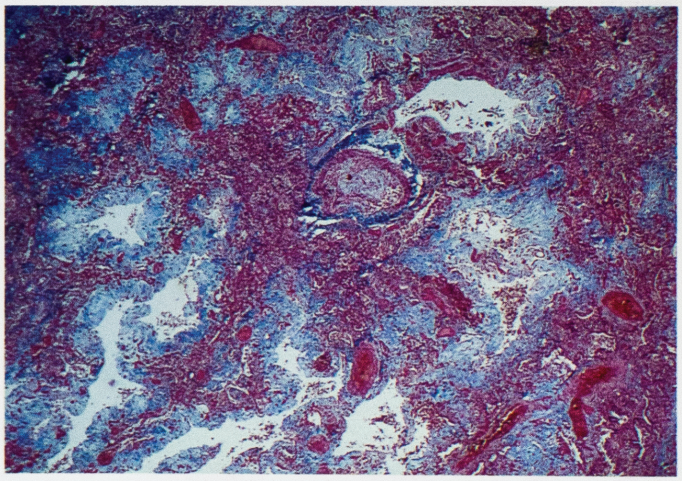
COLOR FIGURE 30-2. In follicular bronchitis and bronchiolitis, marked hyperplasia of bronchial-associated lymphoid tissue produces occlusion of bronchioles. (H & E stain; low magnification; contributed by the editor.)



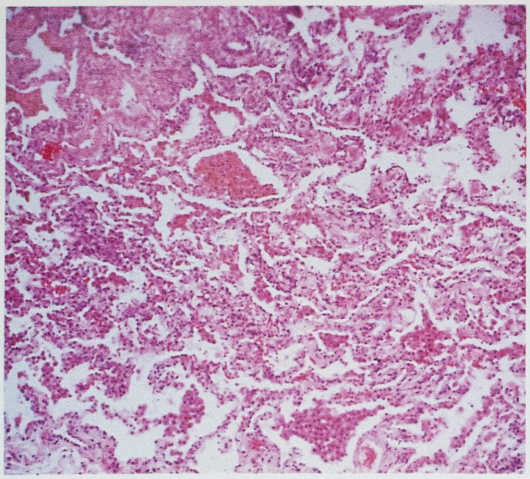
COLOR FIGURE 31-1. Incompletely fixed lung from a patient with acute interstitial pneumonia shows consolidation as a result of fibrosis, which is uniform in distribution. (Contributed by the editor.)



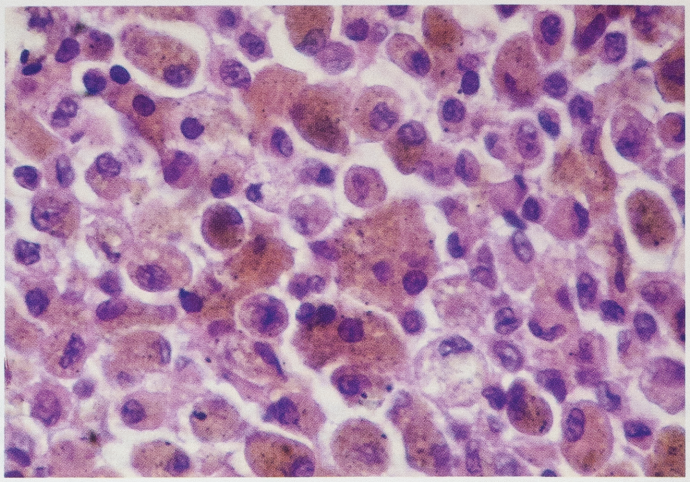
COLOR FIGURE 31-2. A specimen from a patient with an early stage of acute interstitial pneumonia shows fibrosis predominantly within alveolar ducts and adjacent alveoli (*blue areas*). The intervening lung parenchyma is mainly atelectatic. (Masson trichrom stain; low magnification; contributed by the editor.)



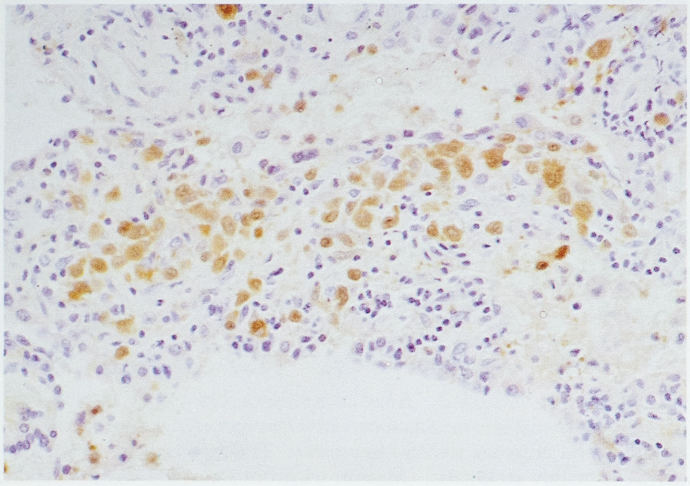
COLOR FIGURE 31-3. Another microscopic field from the same patient as in Color Figure 31-2 shows the fibrosis lining bronchioli and alveolar ducts preferentially; many alveoli are also obliterated by fibrosis, but others are only atelectatic. (Masson trichrome stain; low magnification; contributed by the editor.)



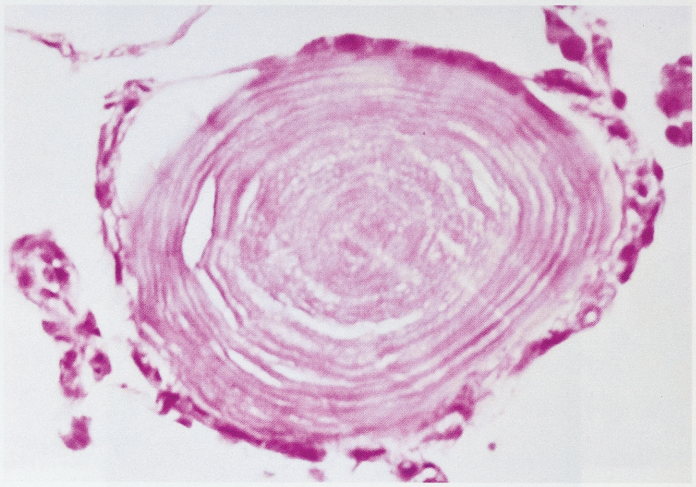
COLOR FIGURE 32-1. A microscopic view of a specimen from a patient with desquamative interstitial pneumonia shows clusters of desquamated cells within alveolar spaces and minimal chronic inflammation and fibrosis of the interstitium. (H & E stain; low magnification; contributed by the editor.)



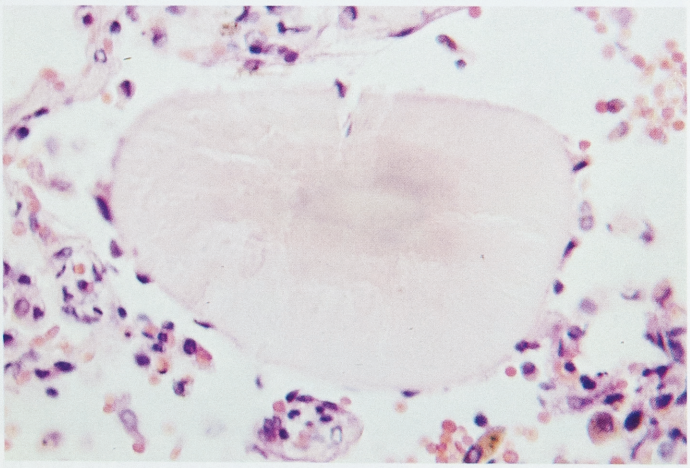
COLOR FIGURE 32-2. Dense intraalveolar collections of macrophages with brownish pigment are present in a heavy smoker with desquamative interstitial pneumonia. (H & E stain; intermediate magnification; contributed by the editor.)



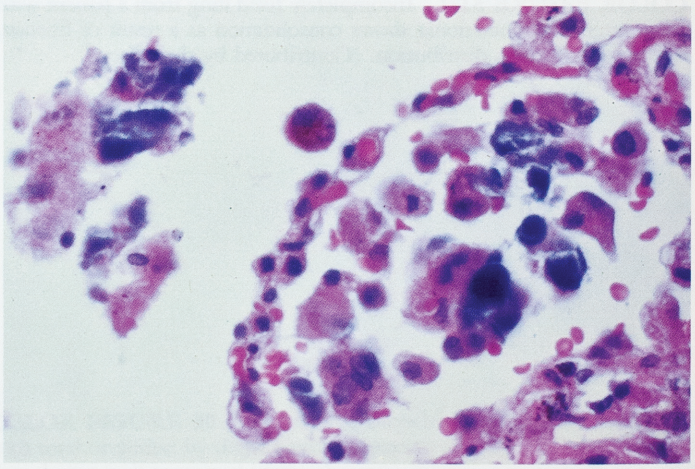
COLOR FIGURE 32-3. Immunoperoxidase stain for S-100 protein is strongly positive in numerous Langerhans cells in a specimen from a patient with eosinophilic granuloma of the lung. (Low magnification; contributed by the editor.)



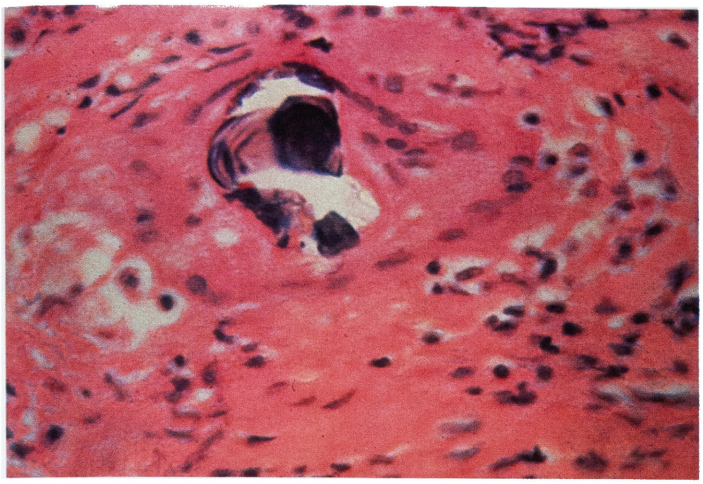
COLOR FIGURE 32-4. A specimen from the same patient as in Figure 32-15 shows the concentric laminated structure of a calcospherite. (H & E stain; intermediate magnification; courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



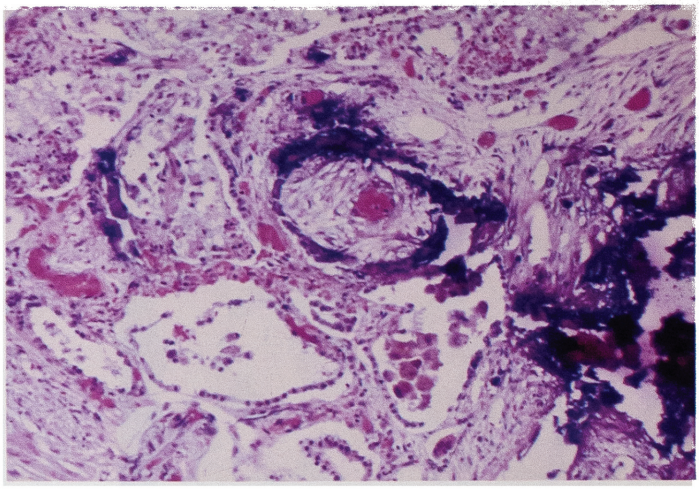
COLOR FIGURE 32-5. In corpora amylacea of the lung, the structure lacks the characteristic concentric laminations of calcospherites seen in pulmonary microlithiasis. (H & E stain; low magnification; courtesy of Jeffrey P. Stead, M.D., Morgantown, WV.)



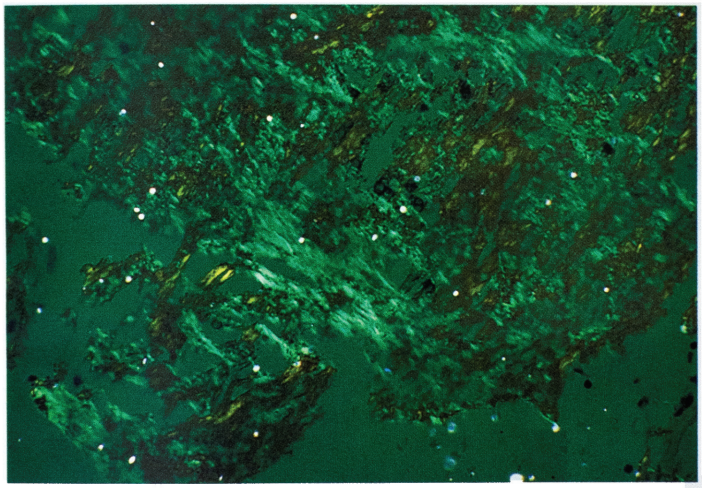
COLOR FIGURE 32-6. An intraalveolar collection of macrophages contains characteristic blue bodies. (H & E stain; intermediate magnification; contributed by the editor.)



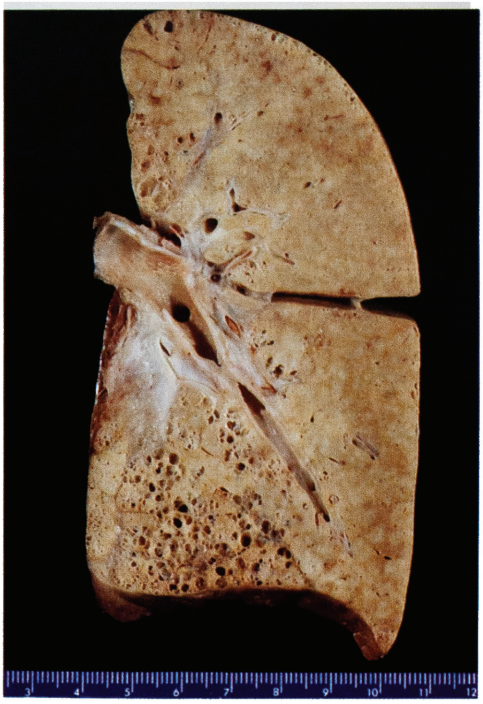
COLOR FIGURE 32-7. A large, calcified Schaumann body lies within a granuloma in a patient with sarcoidosis. (H & E stain; intermediate magnification; contributed by the editor.)



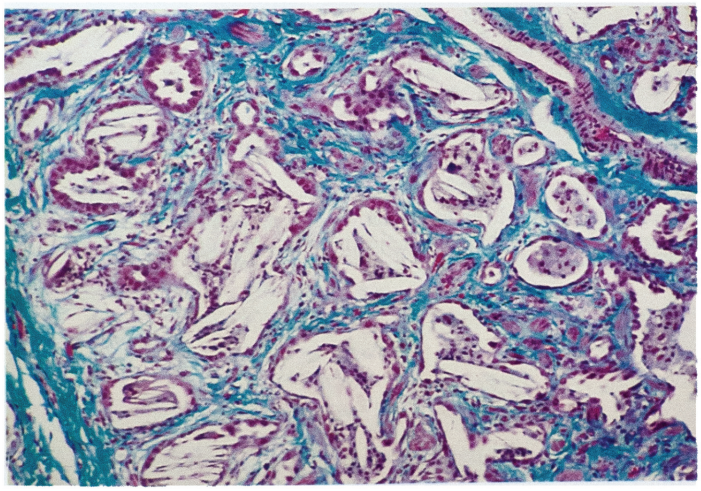
COLOR FIGURE 32-8. Microscopic view of lung tissue from a patient with thrombotic thrombocytopenic purpura and renal failure shows extensive areas of calcification (*blue areas*) admixed with fibrous tissue. (H & E stain; low magnification; contributed by the editor.)



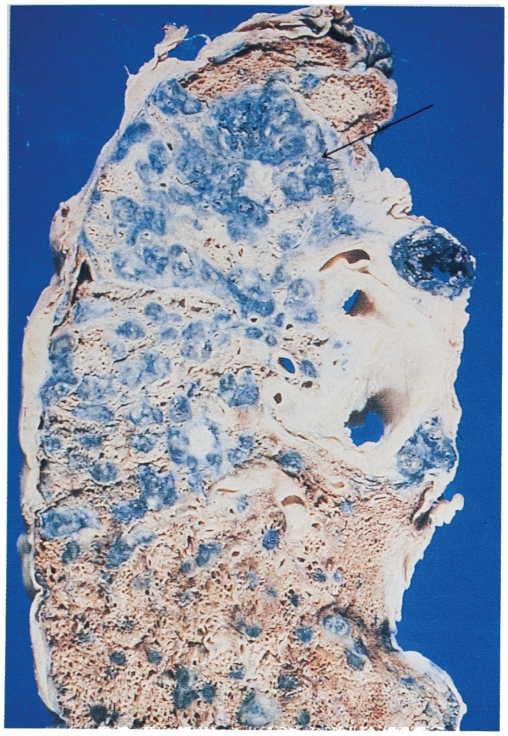
COLOR FIGURE 32-9. Apple green birefringence of amyloid under polarized light is characteristic of nodular amyloidosis of the lung. (Congo red stain; low magnification; contributed by the editor.)



COLOR FIGURE 33-1. The gross appearance of the lung of a patient with endogenous lipoid pneumonia, also referred to as cholesterol pneumonia or golden pneumonia, shows the golden yellow appearance of the pulmonary parenchyma.

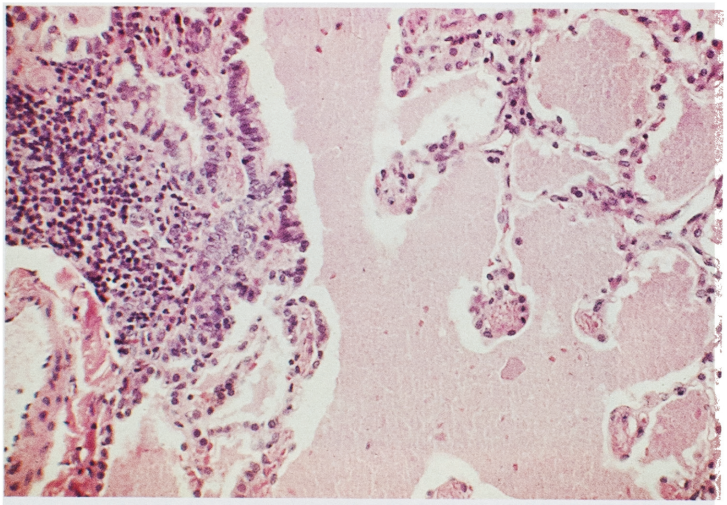


COLOR FIGURE 33-2. Cholesterol granulomas and interstitial fibrosis are seen in an 8-year-old girl (see Table 33-2, case 5) with adenosine deaminase deficiency, severe combined immunodeficiency, and clinically documented gastroesophageal reflux. Fibrosis surrounds the giant cells and cholesterol clefts. (Masson trichrome stain; low magnification.)

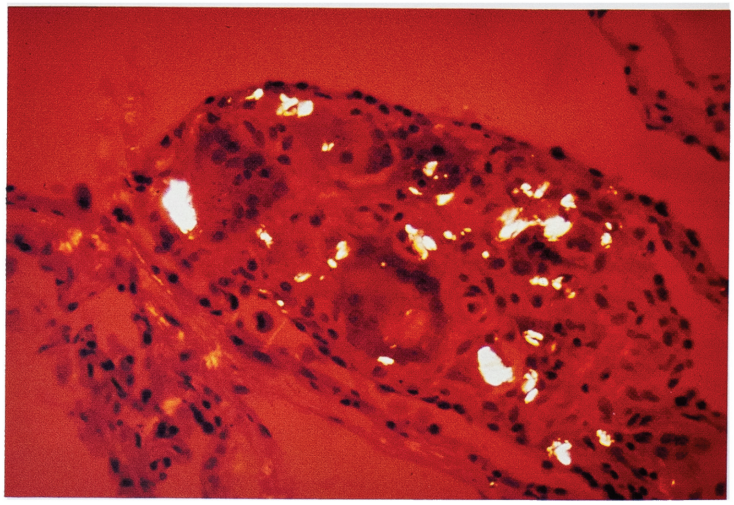


COLOR FIGURE 35-1. A sagittal section of the right lung from a granite worker shows numerous rounded nodules of silicosis admixed with anthracotic pigment. Foci of conglomerate silicosis are present in the upper lobe (*arrow*). (Contributed by the editor.)

COLOR FIGURE 35-2. Advanced silicosis with progressive massive fibrosis is seen in the lung of a granite worker. The upper lobe (*arrow*) is completely scarred and retracted by stony, hard, coalescent nodules admixed with anthracotic pigment. Individual nodules can be seen near and beneath the pleura. (Courtesy of the WAD Anderson Collection, Department of Pathology, University of Miami School of Medicine, Miami, FL.)



COLOR FIGURE 35-3. A microscopic view of acute silicosis in a patient who works as a sandblaster. In addition to the pulmonary alveolar proteinosis filling alveolar spaces, significant lymphocytic infiltrates are seen in the interstitium. (H & E stain; low magnification; contributed by the editor.)



COLOR FIGURE 35-4. A microscopic view under polarized light of a specimen from a drug addict shows extensive silicatosis of lung interstitium. (H & E stain; low magnification; contributed by the editor.)

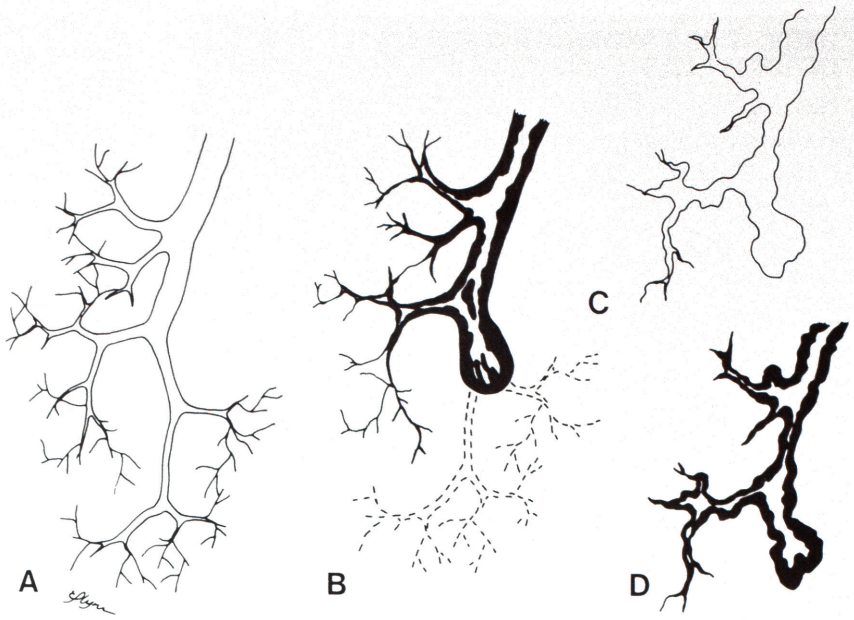


FIGURE 28-5. Pathogenesis of bronchiectasis. (**A**) Normal branching of the bronchial tree shows tapering lumen: progressively from hilum to periphery, the branches arise frequently and are short. Along any pathway, be it distributed centrally or peripherally, the ultimate cluster of airways includes three to five branches a couple of millimeters apart. Each of these is a terminal bronchiole that supplies the respiratory unit, the acinus. The cluster of such acini is a lobule. (**B**) Inflammatory injury to the airway wall caused by endobronchial infection—often with ulceration of the epithelium and even deeper layers of the wall. An endobronchial "embolus" of infected material can start such a process and can be at any level in the airway. (**C**) Even if the inflammation subsides, the airway is left distorted, scarred, and usually obliterated. (**D**) If the infection persists with mucus hypersecretion, the wall continues to show signs of acute inflammation as well as chronic injury.

Distribution

Bronchiectasis is divided into generalized and localized forms; each has implications for treatment. The localized form is sometimes called surgical bronchiectasis, because these patients can be operated on with the expectation of cure. Generalized bronchiectasis is often caused by childhood infections. It may be bilateral, involving the basal parts of the lung, including the lower lobe, middle lobe, and lingula.

Reversible or Irreversible

Reversible bronchiectasis can arise with acute massive collapse or acute infection. Bronchiectasis associated with massive collapse often shows a cylindrical or a varicose, corrugated outline because of the mechanical forces applied to the airway wall. This change is not structural, because it is rapidly reversible with reexpansion of the lung (Fig. 28-6). Sometimes the appearance of the airway during an attack of acute pneumonia can be quite alarming, but it returns to normal over a period of weeks to months.

PATHOGENESIS AND PATHOLOGY

The following are the main mechanisms implicated in the production of bronchiectasis:

- infection with inflammation and ulceration of the airways without significant collapse
- collapse, presumably because of bronchial obstruction, without superimposed infection
- distention of the bronchus without associated infection
- changes in patent airways (Display 28-1).

A major feature that must be ascertained in either the bronchogram or CT scan is the level at which the airway ceases to be patent. In the specimen, the point beyond which filling of the airways ceases should be explored to establish the pathogenesis of airway obstruction.

For the pathologist to understand the lung's appearance in bronchiectasis and the pathogenetic mechanisms at work, it is essential that he or she appreciate the importance of collateral ventilation.[5] Because the connective tissue septa within a lobe do not completely isolate secondary lobules, air can drift between acini, lobules, and segments.[6,7] Only the pleura isolates an end unit from collateral ventilation, and because the oblique fissure between the upper and lower lobes is incomplete in about 50% of subjects, even a lobe is not always isolated from its neighbor.

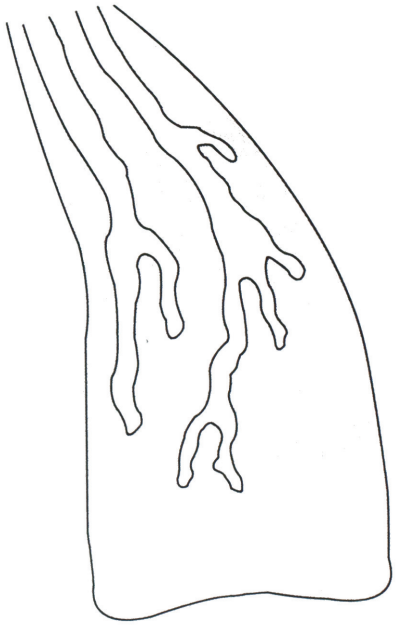


FIGURE 28-6. In massive collapse, the peripheral airways, like alveoli, collapse. The lobe becomes like a pancake—the central airways fold like a fan, and the distal lung shrinks up toward the hilum. Only the large bronchi with abundant cartilage in their walls stay patent, and because mechanical forces have changed, their lumen becomes dilated and their outline irregular.

DISPLAY 28-1. PATHOGENESIS OF BRONCHIECTASIS

Infection*

Predisposing diseases or factors

Cystic fibrosis
Immune deficiency
Toxic inhalation injury
Aspiration injury
AIDS
Lung Transplantation

Impaired Mucociliary Clearance

Ciliary dyskinesia
Kartagener syndrome
Young syndrome

Hypersensitivity

Bronchial asthma
Bronchopulmonary aspergillosis

Airways Obstruction

Luminal
Foreign-body aspiration
Mucus plug
Endobronchial tumor
Wall stenosis or obliteration
Wall compression
Lymph node enlargement
Extrabronchial tumor
Inflammation
Noninfective
Chemical aspiration
Gastric reflux

* *The organisms responsible can usually be predicted* (e.g., Pseudomonas *spp. in cystic fibrosis,* Staphylococcus *spp. in chronic granulomatous disease,* Pneumocystis carinii *and* Mycobacterium *spp. in AIDS*).

The anatomic pathways of collateral drift are the pores of Kohn in the alveolar wall, and the accessory bronchioloalveolar channels of Lambert, between distal bronchioles and adjacent alveoli. Even in those parts of the lung where septa are relatively numerous (*e.g.*, tip of the lingula, right middle lobe, costodiaphragmatic rim), they do not completely isolate a lobule; there is always some corridor of alveolar tissue between adjacent units.

In the lung of a newborn infant, collateral ventilation does operate, although it is less efficient than in older lungs. Pores of Kohn are present, but the channels of Lambert probably do not come in until some years later. Also, the pores of Kohn increase in size as the lung gets bigger and alveoli multiply.

Collateral ventilation is of critical importance for the pathologist and radiologist in their interpretation of lung changes. It is important to realize that because of collateral ventilation, the presence of aerated lung does not mean that the airways supplying that part of the lung are patent.

Infection With Inflammation and Ulceration

Infection can cause bronchiectasis by inflammation and ulceration of bronchi. If a bronchogram is performed, incomplete peripheral filling is usually seen because of secretions and lumen narrowing, although the airway may not be obliterated. If caught early enough and treated, such a stage is potentially reversible.

Typically, infections producing cystic and varicose bronchiectasis cause a severe degree of inflammation and ulceration that encompasses the epithelium, the gland layer, muscle, cartilage, and even the adventitia. The development of an endobronchial abscess leads to destruction of a large amount of adjacent lung tissue (Fig. 28-7). Even if healing occurs and the cavity is lined with continuous epithelium, the distal part of the airway will no longer be in communication with the proximal airway.

Such infection and abscess formation can occur at any level along the airway wall and can be a single lesion or widespread and numerous. Endobronchial embolus is used to describe the aspira-

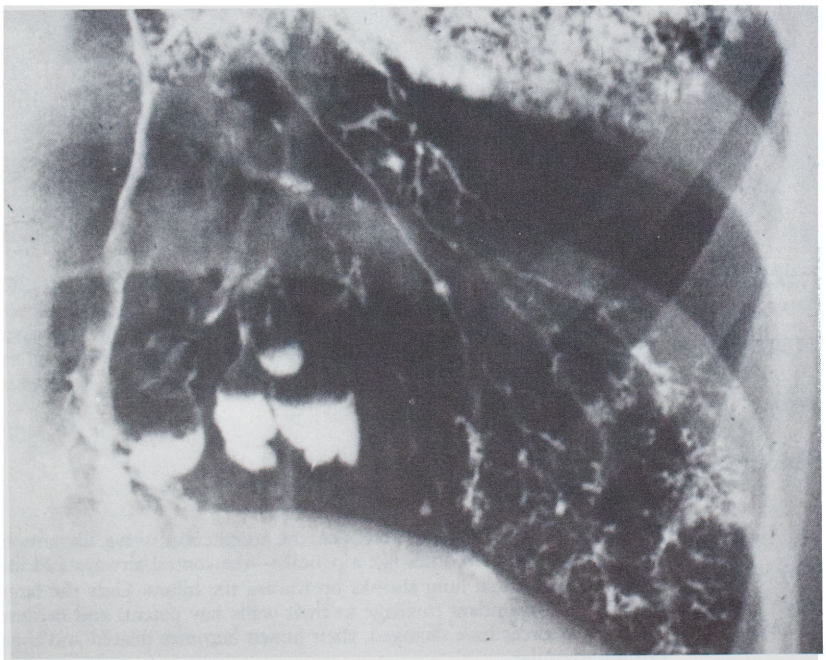


FIGURE 28-7. Bronchogram in an adult reveals an endobronchial abscess cavity resulting from aspiration of pus and blood after tooth extraction under general anesthesia. The lobe is aerated through collateral ventilation.

tion of infected material that causes the development of such bronchiectasis. This may represent simply pus and mucus with retained bacteria moving down the airway, an inhaled foreign body, or inhaled infected secretions from an upper respiratory tract infection. In such lesions, a chronic, indolent infection typically establishes itself. Even if there is healing with resolution of the infection, stenosis and scarring persist. It is in this way that localized but severe damage to the airways may occur even after a single episode of severe infection.

Collapse

Complete obstruction of an airway is often associated with retention of secretions distal to the blockage. Such obstruction is not necessarily associated with collapse or airlessness of the segment because of the effective functioning of collateral ventilation. However, when present, massive collapse of a lobe or lung is associated with a special form of bronchiectasis (see Reversible or Irreversible).[8,9]

The best way to appreciate the effect of such collapse is as a solitary change involving a lobe or lung. If this happens suddenly, as with obstruction of the main airway, the lobe may rapidly become airless, probably in an hour or so. The alveoli, bronchi, and bronchioles collapse so that their walls are in apposition. Only the proximal 5 or so of the 25 or more generations along an axial airway have enough cartilage in their wall to stay patent[10]; the small bronchi and bronchioles collapse around the patent central airways. This means that not only does the collapsed lobe close down at the hilum like a fan, but the peripheral airways shrink up toward the hilum.

This is well illustrated in the shadow of the collapsed lower lobe seen behind the heart in Figure 28-8, where both the length and the width and thickness of the lobe are reduced. Because the walls of the airways have fallen into apposition, this gives a rat-tail appearance to their outline. The central airways appear irregular and corrugated, presumably because of the change in the distribution of mechanical forces within the lobe.

In the airless part, the alveolar epithelium is in apposition and the capillaries in the wall of the alveoli are dilated so that the tissue appears congested and sinusoidal, like liver or spleen.[11] Blood flow through the lobe is reduced. Such collapse is reversible, certainly up to several years; however, it becomes irreversible either by the lapse of time or by the development of super-added infection at the blind endings of the airways.

The development of such an infection may produce localized endobronchial abscesses and saccular bronchiectasis (see Fig. 28-7). A bronchiectatic sac will remain when the massive collapse reverses; this is one way localized cystic bronchiectasis may develop in acuated lung.

Distention

Dilatation may develop behind an intraluminal obstruction such as a tumor, foreign body, or mucus plug. The retention of secretions with or without added infection leads to dilatation of the airway; the distal airways are typically patent. The pathologist who sees such an occluded airway is more likely to use the words "mucocele" or "secretion retention cyst" than "bronchiectasis"; however, if the dilatation remains after the foreign body or tumor is removed, then the term "bronchiectasis" will certainly be appropriate. The presence of a mucocele in association with bronchial atresia is illustrated in Figure 28-9.

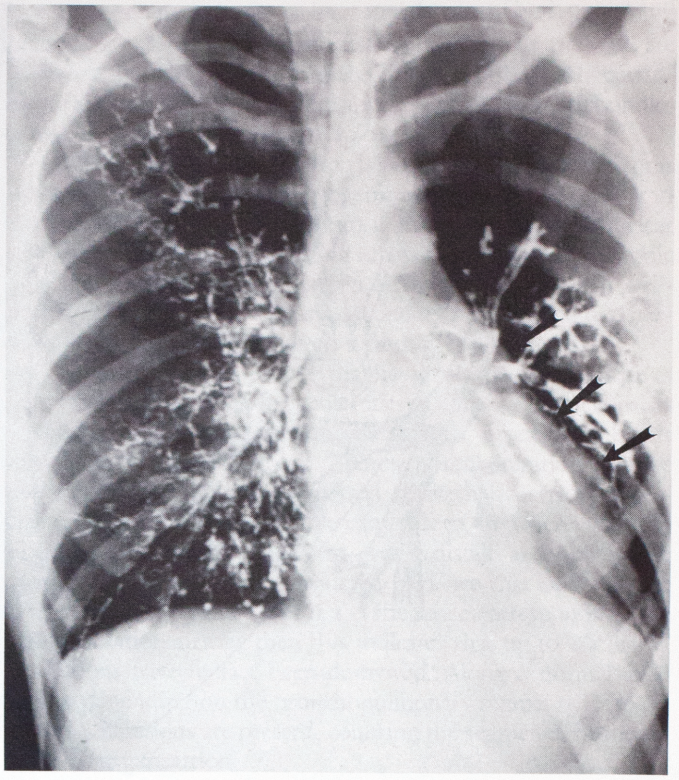


FIGURE 28-8. A bronchogram shows massive collapse of the left lower lobe seen behind the heart (*arrows*). There is also bronchiectasis of the lingula, although collateral ventilation has maintained aeration.

The various pathogenetic mechanisms may operate separately, or more than one may be present at any given time. Enlarged lymph nodes associated with tuberculous infection are a common cause of central airway obstruction with massive collapse. Ulceration of the airway epithelium due to erosion by tuberculous nodes with discharge of caseous material causes localized infection of both bronchus and lung parenchyma. The outcome of such lesions is a persistently airless or a reaerated lobe with cystic bronchiectasis at various levels and with cysts of different sizes.

Patent Airways

Mucus hypersecretion due to mucous gland hypertrophy is the basis of sputum production in patients with bronchiectasis. In the large central bronchi, mucous gland hypertrophy is a common feature, whereas in the lobar and segmental bronchi it is often associated with dilatation of the ducts of the mucous glands. In the specimen, these can be seen as open mouths or small holes in the wall of the airway. In the bronchogram, the radiopaque material usually flows into the mouths of these ducts, which appear as small protuberances up to 2 mm long and 1 mm wide. With peripheral bronchiectasis, the trachea is often dilated with tortuous outpouchings of the epithelium between the cartilage. Calcification of the tracheal cartilage is often present.

Measurement of mucous gland hypertrophy is conveniently made by assessing the gland-to-wall ratio (see Chap. 27).[12] In the normal airway, this is about 1 : 4, but usually less than 1 : 3. Some

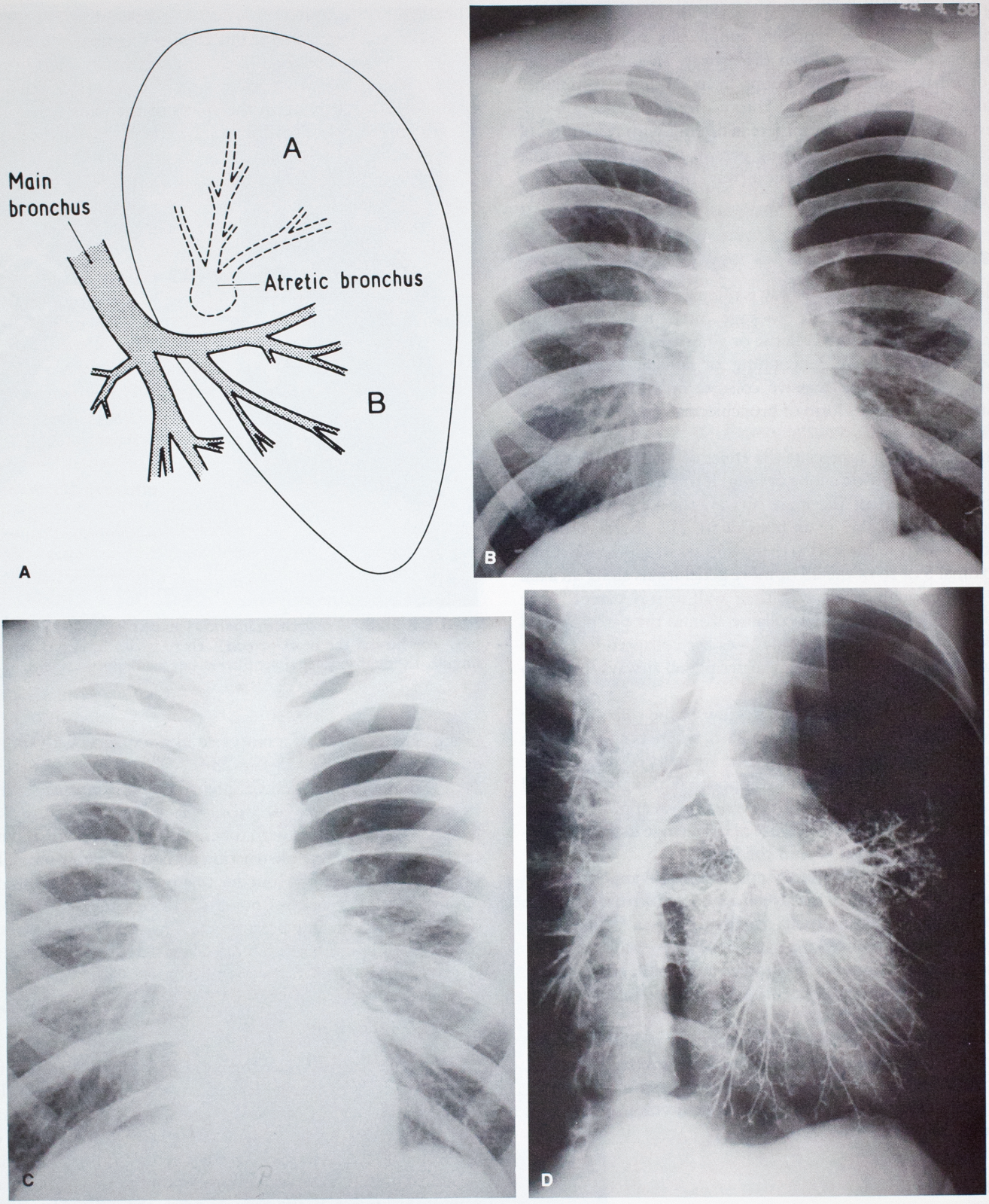


FIGURE 28-9. Atresia of bronchus with mucous cyst. (**A**) The diagram shows that region A is supplied by an atretic bronchus that lacks a central communication but has normal peripheral branching. Collateral ventilation provides aeration for this region. Region B is supplied by patent airways. (**B**) In an inspiratory chest radiograph of a patient with left upper lobe bronchial atresia, the left upper lobe is hyperlucent and lacks bronchovascular markings. (**C**) Chest radiograph of the same patient as in (**B**) during expiration. Because of air trapping and reduced volume in the rest of the lung, left upper lobe hyperlucency is accentuated. (**D**) A bronchogram of the same patient shows absence of bronchial filling in the hyperlucent zone and normal filling in the lower lobe and lingula. (**E**) Cut surface of the resected left upper lobe from another patient reveals a central cystic atretic bronchus filled with mucus. Air trapping produces emphysema. The lobe is devoid of soot pigment because aeration is by collateral ventilation. (From deMello DE, Davies P, Reid LM. Lung growth and development. In: Simmons D, ed. Current pulmonology. vol. 10. Chicago: Year Book, 1989:159.)

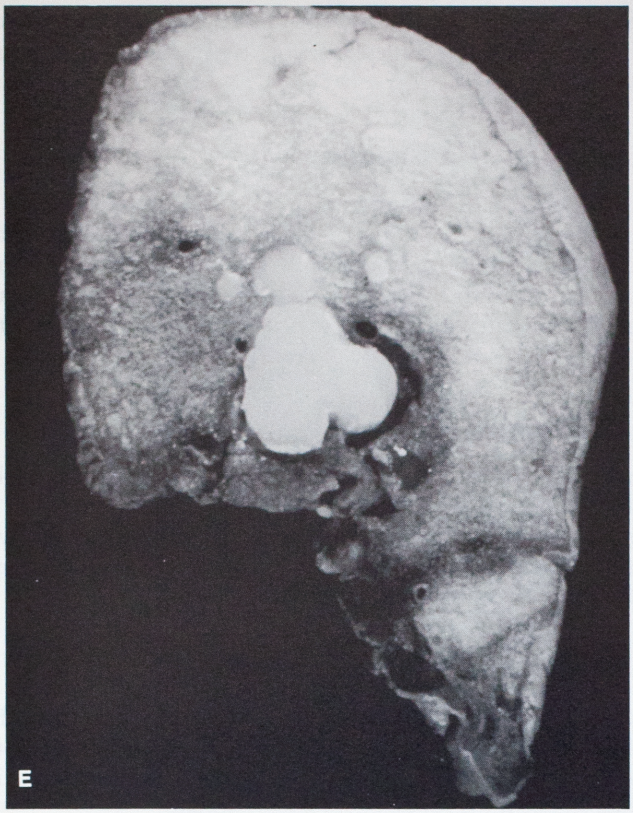


FIGURE 28-9. *(Continued)*

degree of hypertrophy develops before sputum production becomes chronic. If a patient has persistent sputum production, this gland-to-wall ratio is invariably increased.

In localized bronchiectasis, the changes are typically confined to the lobe containing the bronchiectasis. When the disease is bilateral, the lobar bronchi may be more significantly affected, and there is a degree of gland hypertrophy even in the more central airways. The hypertrophy affects the mucous acini more than the serous. Increased vascularity is apparent in the hypertrophied glands whether or not inflammatory cell infiltration is present. The surface epithelium shows increased density of both goblet and ciliated cells. Apart from the mucus-secreting tissues, the walls are thickened by an increase in fibrous connective tissue and hypertrophy of the muscle. The wall often appears corrugated with bundles of smooth muscle lying in the apices of the folds.

Inflammatory cell infiltration is variable. Even if the patient is producing purulent sputum, pyogenic cells may not be striking in the airway wall; if the epithelium is intact, polymorphonuclear leukocytes may be seen migrating across the epithelium. Chronic inflammation may be apparent in airways of all sizes. In well-established cystic bronchiectasis, secondary proliferation of *Aspergillus* species frequently leads to a fungus ball (Fig. 28-10).

The endobronchial abscess that has produced ulceration gives a saccular space or cystic bronchiectasis in which the wall consists of connective tissue without muscle, glands, or cartilage but is covered by intact epithelium. Stenosis or obliteration may be relatively localized and interspersed between hypertrophic sections of the wall. Such a saccule can be seen anywhere along an airway as a relatively isolated event, even as distally as the pleura. At this position it was once considered evidence that such a space derived from bronchioli, but if a cystic space corresponds to the fifth-generation airway, then this indicates that up to 20 airway generations have in fact been destroyed. Along a normal axial airway, depending on the bronchopulmonary segment, 15 to 25 airway generations are present, counting the segmental bronchus as the first generation.

When a cystic bronchiectasis is deep in the lung, it is often possible to trace the remnants of airways beyond the cavity. The walls of such airways are often intact but no longer in communication with proximal, more central airways. Such remnants, particularly if the lesions developed in childhood, can be atrophic.

When a lobe is involved by pneumonia, the infection involves not just the airway space but also the surrounding alveoli. Here, scarring with partial airlessness and reduction in volume is also part of the picture. Bronchiolitis obliterans and regions of nodular fibrosis are seen. Microscopic carcinoid tumors (*i.e.*, tumorlets[13]) are common at this stage, as are pathologic changes of the pulmonary vessels. The lymph nodes at the hilum may also be enlarged, and during acute infection the lymph node enlargement may cause compression of the central airways.

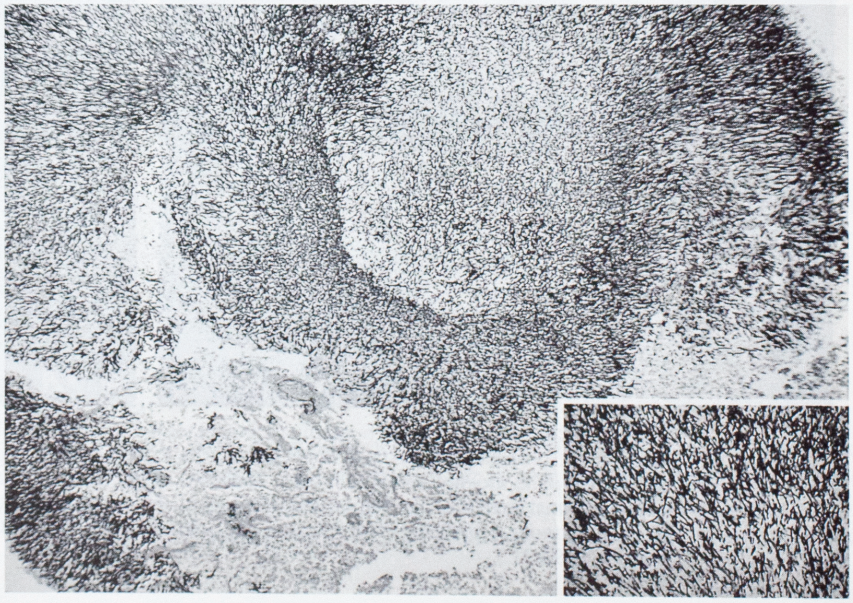


FIGURE 28-10. A photomicrograph of an airway in a patient with cystic fibrosis reveals a fungus ball produced by the branching hyphae of *Aspergillus* sp. (Gomori methenamine silver stain; panoramic view; inset at low magnification.)

ASSOCIATED DISEASES

Cystic Fibrosis

In cystic fibrosis (CF), infection is present throughout both lungs.[14] At birth, the lungs appear grossly normal; however, they are abnormally susceptible to infection (Fig. 28-11). A vicious cycle of mucus hypersecretion with retained secretions, colonization by bacteria, inflammation, and infection develops. The viscosity of the CF sputum reflects its cellularity (*i.e.*, pus) and glycoprotein content. Pus of the patient with CF is not more viscid than that of the bronchitic. There is no evidence that the glycoprotein of the CF patient is abnormal.

The entire lung can be involved, with bronchitis and bronchiolitis occurring in all lobes, apically and basally. Airlessness of a lobe with massive collapse is less common with collateral ventilation effectively maintaining aeration of the lobes. Lung function studies show diffuse airways obstruction and major disturbance of lung function (see Chap. 11).

Mounier-Kuhn Disease

Mounier-Kuhn disease is a rare developmental condition in which there is an unexplained but diffuse dilatation of the trachea and large cartilaginous airways of the lung.[15] Typically, this condition does not present until adulthood. The peripheral airways are usually of normal size. It is possible that this represents acquired bronchiectasis because these patients seem prone to recurrent infections (see Chap. 9).

Immotile Cilia Syndrome

In the immotile cilia syndrome (Fig. 28-12), the bronchiectasis is typically of the acquired type.[16–22] It is basal and gravitational, indicating failure of mucociliary clearance with retention of infected secretions in the basal region. In the special case of Kartagener syndrome, in addition to bronchiectasis there is sinusitis and situs inversus (see Chaps. 9 and 11).

Agammaglobulinemia

The bronchial disease of agammaglobulinemia seems to be peripheral,[23–25] whereas in Kartagener syndrome the main problem is proximal aspiration of infected material from the upper airways. Little detailed analysis has been made of the distribution and nature of the bronchiectasis in these conditions.

Williams-Campbell Syndrome

As noted, when the lesions of bronchiectasis affect bronchi in the young, small, and still growing lung, the growth of airways both proximal and distal to the obstruction is impaired. The growth in

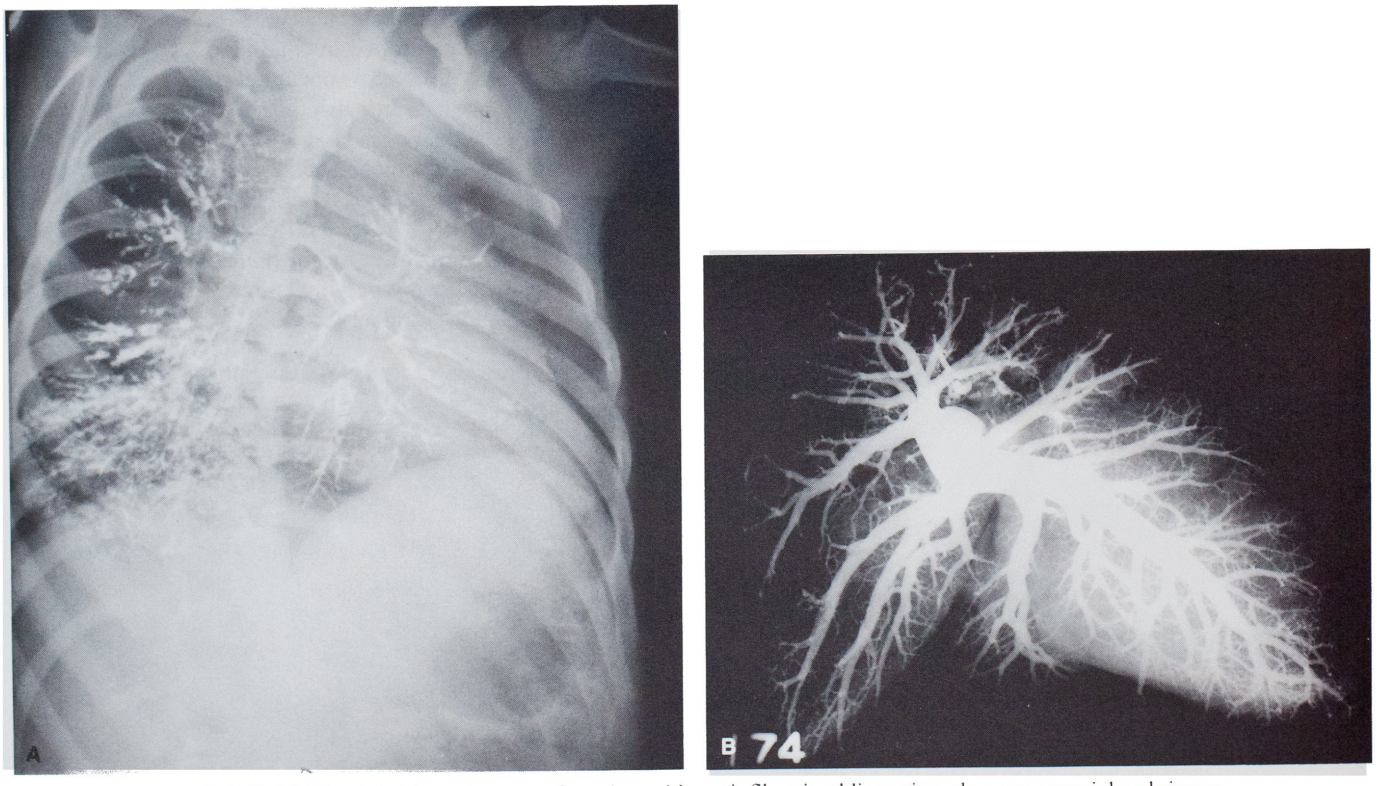


FIGURE 28-11. (**A**) A bronchogram of a patient with cystic fibrosis, oblique view, shows poor peripheral airway filling due to bronchiolitis. (From deMello DE, Davies P, Reid LM. Lung growth and development. In: Simmons D, ed. Current pulmonology. vol. 10. Chicago: Year Book, 1989:159.) (**B**) A right lung arteriogram of another patient, shows a normal arterial branching pattern, although there is peripheral pruning. (From Tomashefski JF, Vawter GF, Reid L. Pulmonary pathology. In: Hodson ME, Norman AP, Batten JC, eds. Cystic fibrosis. London: Bailliere Tindall, 1983:31.)

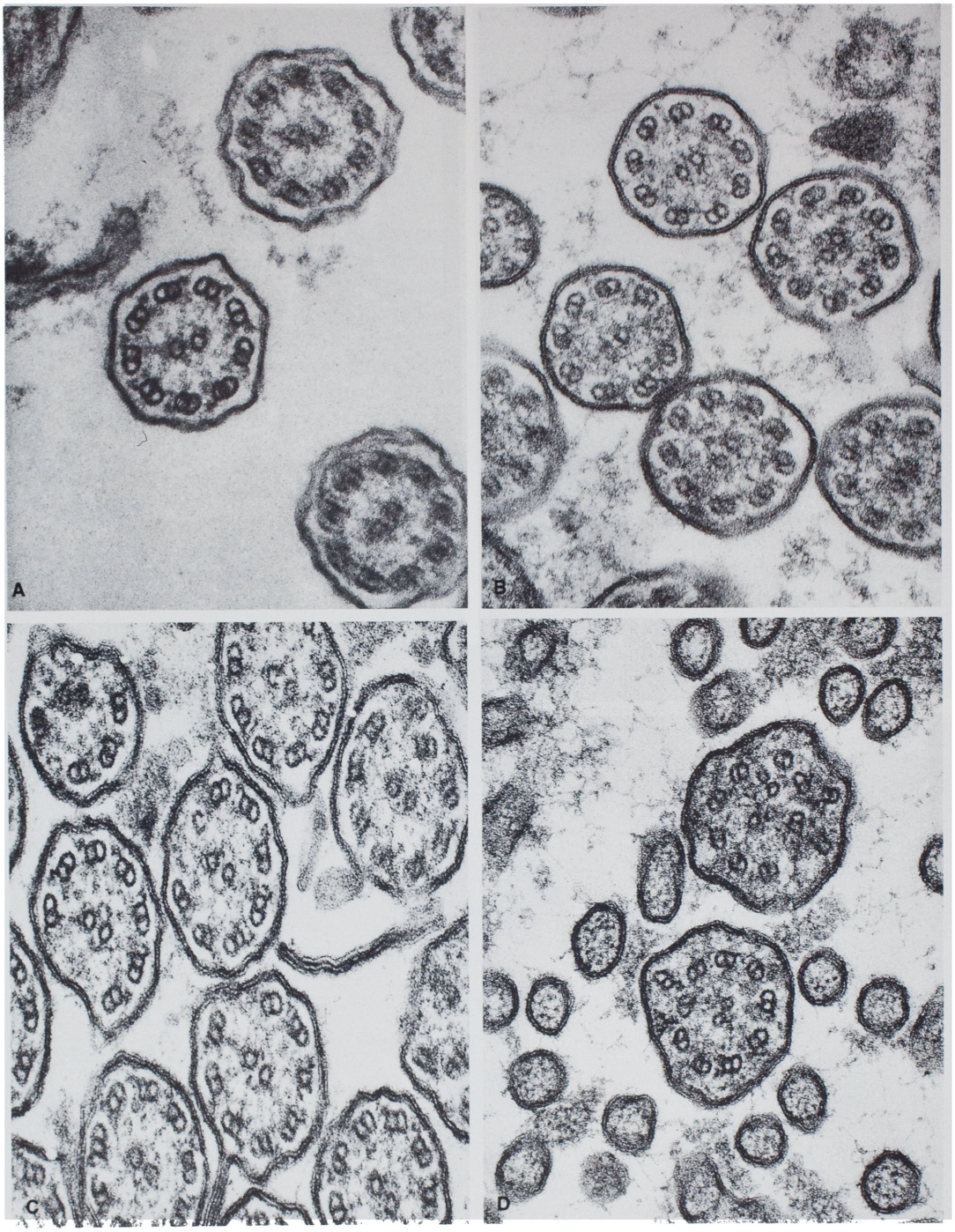


FIGURE 28-12. Electron micrographic appearance of cilia in the immotile cilia syndrome. (**A**) Normal. (**B**) Absent dynein arms. (**C**) Loss of outer doublet. (**D**) Supernumerary doublet.

lung size that occurs between 1 year of age and adulthood is striking.[26] If ventilation-perfusion is impaired because of the patchy disease of bronchiectasis, then it is not surprising that the airways to a given lobe are small and distorted and their cartilage does not look normal for the age of the child.[3,10] This does not, however, indicate that the disorder is congenital.

Macleod Syndrome

Macleod syndrome is characterized by unilateral dry bronchiectasis or bronchiolectasis. It is a situation in which one lung is normal and the other is virtually nonfunctioning. Sometimes in patients with Macleod syndrome it is apparent that there is also

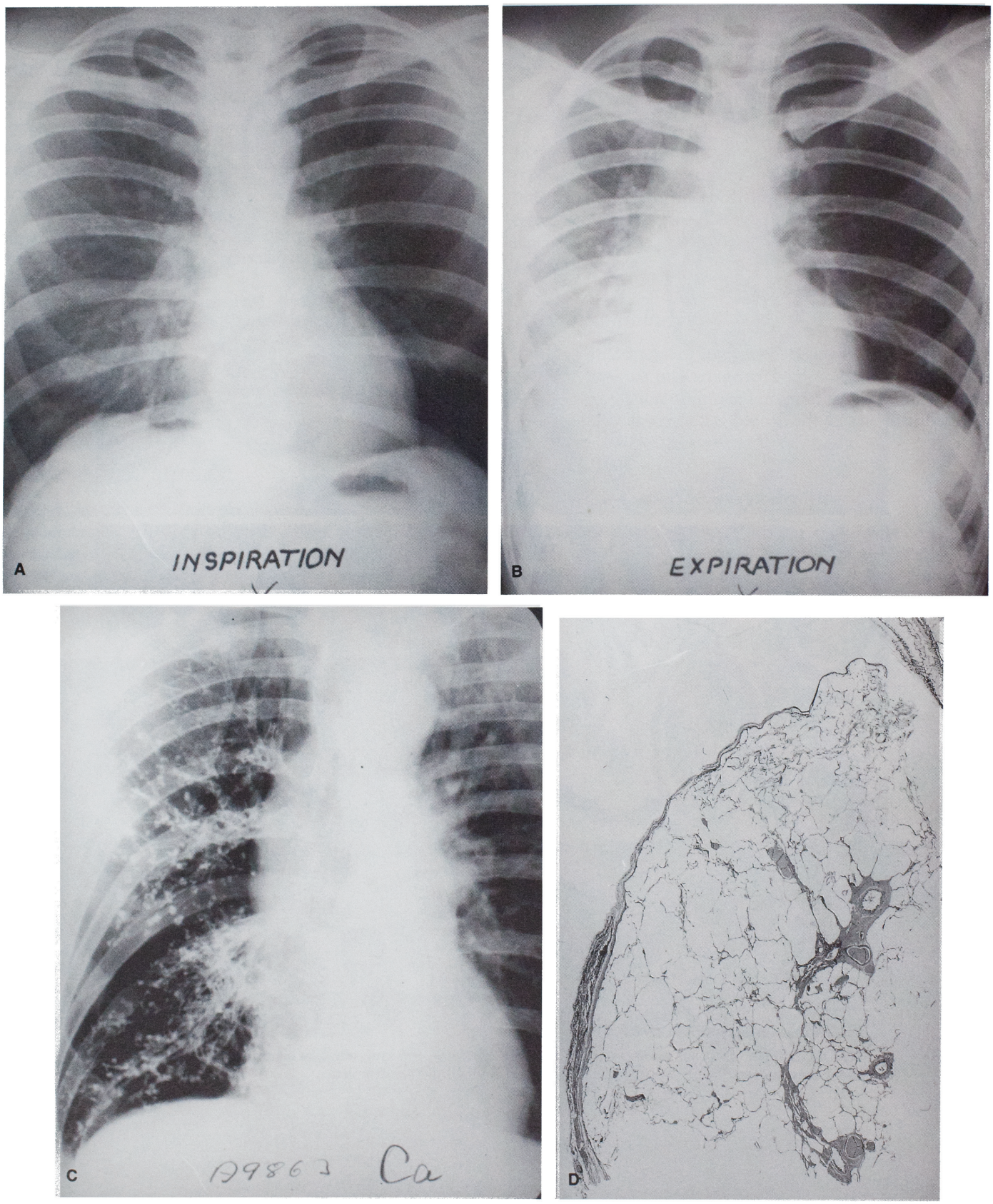


FIGURE 28-13. Macleod syndrome. (**A**) Inspiratory chest radiograph shows unilateral hypertranslucency of left lung with a decrease in vascular markings. (**B**) During expiration, the patient in (**A**) shows air trapping in the left lung and a right shift in mediastinal structures. (**C**) Bronchogram in another patient with Macleod syndrome shows bronchiolectasis (*i.e.*, dilated cystic small airways because of bronchiolitis obliterans). (**D**) A photomicrograph of a resected lung from another patient shows emphysematous alveoli distal to the obstructed airways; these alveoli are aerated by collateral ventilation and have failed to multiply normally. (H & E stain, panoramic view; from deMello DE, Davies P, Reid LM. Lung growth and development. In: Simmons D, ed. Current pulmonology. vol. 10. Chicago: Year Book 1989:159.)

patchy change in part of the seemingly normal lung.[27–30] These patients are at considerable risk if any further deterioration in function occurs (Fig. 28-13; see Pulmonary Circulation).

PATHOPHYSIOLOGY

If the bronchiectasis is widespread, as in CF or chronic bronchitis, the major problem is usually shortness of breath. Lung function tests show the pattern of airways obstruction typical of chronic bronchitis. In more localized types of bronchiectasis, the patient usually presents with the symptoms of sputum production or hemoptysis. Even when bronchiectasis is bilateral and seems to affect most of the lower one half of both lungs, if the upper lobes are relatively spared, lung function can be relatively satisfactory. If both lungs are diffusely diseased, there is major limitation of function.

Bronchial Circulation

Virtually any pathologic lesion in the lung receives blood supply from the bronchial artery. Tumors, pneumonia, lung abscess, and pulmonary embolus all cause an increase in bronchial artery flow with communications developing with the pulmonary artery bed. In bronchiectasis, the larger the airway affected, the greater the flow. In bronchiolitis or lesions of small airways, increase in flow seems less important. When an endobronchial abscess develops, anastomoses from bronchial artery to pulmonary artery can directly form in the granulation tissue.

Hemoptysis is characteristic of later stages of the lung changes of CF and is a major clinical problem (Fig. 28-14). The hemoptysis of bronchiectasis is typically bright red blood and is assumed to be from the bronchial circulation. Often, large arteries are identified in the immediate subepithelial region, and relatively minor trauma leads to hemorrhage.

Pulmonary Circulation

Where there is obstruction to airways, ventilation is reduced, with a consequent reduction in pulmonary artery flow. If there is reduced ventilation over a long period of time, then the vascular bed probably atrophies. The occurrence of these events before lung growth is complete causes major interference with lung development. In a part of the lung supplied by an obliterated

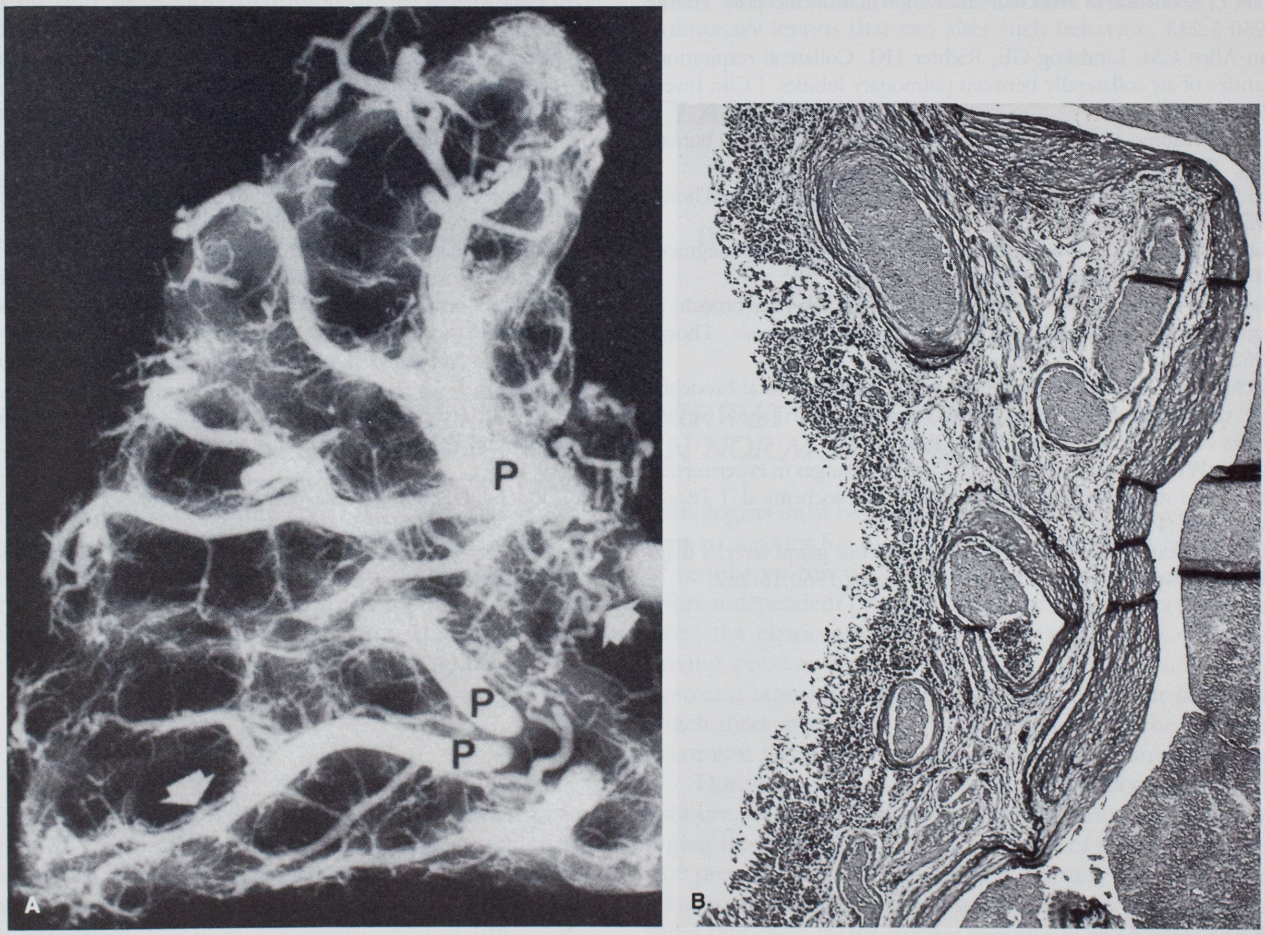


FIGURE 28-14. (**A**) Postmorten arteriogram of a bronchiectatic upper lobe in a patient with cystic fibrosis shows large pulmonary artery branches (P) extending to the pleural surface; peripheral filling is markedly decreased. Bronchial arteries (*straight arrows*) are narrow and form a plexus at the hilum; they travel with the airways and pulmonary arteries in the bronchoarterial bundle to the pleural surface. (**B**) Photomicrograph of a lung of a patient with cystic fibrosis shows focal ulceration of the lining epithelium in a bronchus and dilated bronchial arteries in the wall. (H & E stain, panoramic view; from Tomashefski JF, Vawter GF, Reid L. Pulmonary pathology. In: Hodson ME, Norman AP, Batten JC, eds. Cystic fibrosis. London: Bailliere Tindall, 1983:31.)

bronchiectatic bronchus, even if that lung is still aerated, there is distention of the alveoli and thinning of their walls (*i.e.*, a region of hypoventilation and hypoperfusion). The interaction of these events is well seen in Macleod syndrome,[30] where flow to the affected lobe or lung and ventilation are extremely low.[28,29]

The importance of the pulmonary circulation can be seen where hypoxia and hypoxemia supervene, as in diffuse bronchiectasis and bronchiolectasis of CF.[31] In addition to airway problems, cor pulmonale develops, usually in the last year of life. A rise in pulmonary artery pressure due to hypoxic vasoconstriction contributes, but the critical factor is the structural remodeling of the microcirculation causing restriction of vascular volume.[32] It is rare to see polycythemia in children with bronchiectasis.

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