

Pictorial Essay

Asthma and Associated Conditions: High-Resolution CT and Pathologic Findings

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Asthma is an inflammatory disease of the lungs characterized by increased airway reactivity to various stimuli and by airflow obstruction that is at least partially reversible. High-resolution CT manifestations of asthma include thickening of the bronchial wall, narrowing of the bronchial lumen, areas of decreased attenuation and vascularity on inspiratory CT scans, and air trapping on expiratory CT scans [1–3]. Other findings that are seen with increased frequency in patients with asthma are bronchiectasis and emphysema [1, 2]. Asthma is associated with several complications including atelectasis, pneumonia, mucoid impaction, allergic bronchopulmonary aspergillosis (ABPA), bronchocentric granulomatosis, eosinophilic lung disease, and Churg-Strauss syndrome.

The aim of this pictorial essay is to illustrate the high-resolution CT manifestations of asthma and associated conditions and to compare the CT findings with the pathologic findings.

High-Resolution CT and Histologic Manifestations of Asthma

Bronchial Abnormalities

Histologically, asthma is characterized by the presence of chronic inflammation of the

airways that involves mainly the medium-sized and small bronchi [4]. The bronchi are thickened by the combination of edema and an increase in the amount of smooth muscle and in the size of the mucous glands (Fig. 1). These histologic changes are manifested on high-resolution CT by the presence of bron-

chial wall thickening and narrowing of the bronchial lumen (Fig. 2).

The prevalence of bronchial thickening on high-resolution CT in patients with asthma reported by various authors ranges from 44% to 92% [1–3]. The wide variability in prevalence is presumably related to the subjective nature

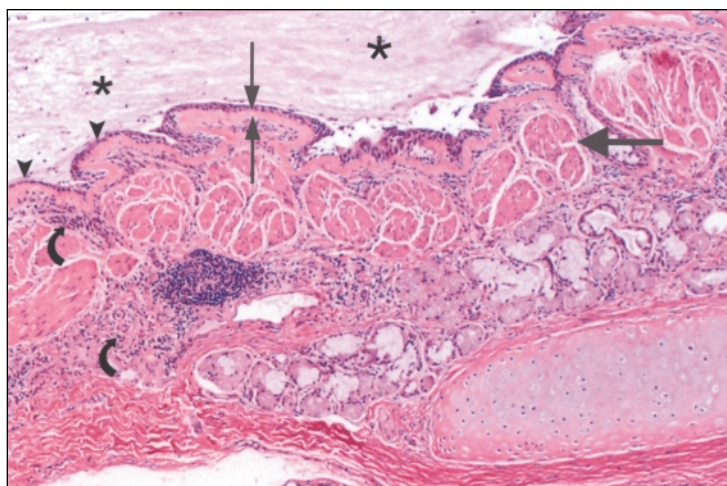


Fig. 1.—Photomicrograph of autopsy specimen obtained in 10-year-old boy with fatal asthmaticus reveals bronchus with luminal mucus plug (asterisks), thinning of surface mucosa (arrowheads), and submembranous fibrosis (so-called basement membrane thickening) (vertical straight arrows), muscle hypertrophy (horizontal straight arrow), and inflammatory infiltrate (curved arrows) that is rich in eosinophils. (H and E, low magnification)

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Fig. 2.—High-resolution CT scan obtained in 72-year-old woman with chronic asthma shows bronchial wall thickening (*large arrows*) with associated narrowing of bronchial lumens. Also noted are subtle areas of decreased attenuation and vascularity (*small arrows*), which are more clearly seen in Figure 3.

of the assessment and different patient populations. Park et al. [3] identified bronchial wall thickening in 17 (44%) of 39 asthmatic patients compared with only 4% of healthy control subjects. Bronchial wall thickening was more prevalent among patients with severe airflow obstruction (83% of patients with forced expiratory volume in 1 sec [FEV₁] that was < 60% of predicted volume) than in patients with mild obstruction (35% of patients with FEV₁ ≥ 60%). Park et al. assessed the degree of bronchial narrowing by objectively measuring the ratio between the short-axis internal bronchial diameter and the short-axis diameter of the accompanying pulmonary artery. Asthmatic patients with an FEV₁ of less than 60% of

predicted volume had a lower bronchoarterial-diameter ratio (mean ± SD, 0.48 ± 0.11) than patients with mild airway obstruction (0.60 ± 0.18) or healthy subjects (0.65 ± 0.16) ($p < 0.01$) [3].

In patients with asthma, most of the bronchi have normal or decreased internal diameters; however, in approximately 30–40% of adult patients with uncomplicated asthma, one or more bronchi are dilated [2, 3] (Fig. 3). The presence of bronchiectasis does not correlate with the severity of airflow obstruction in these patients [2, 4]. The bronchiectasis seen in patients with uncomplicated asthma typically is cylindrical, and the bronchoarterial-diameter ratio is less than 1.5 [1, 5].

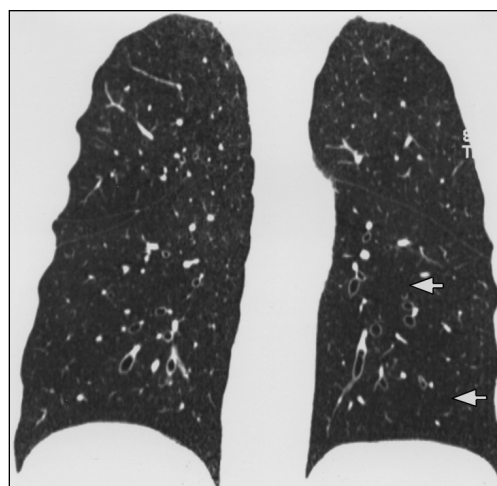
Bronchiolar Abnormalities

Histologic bronchiolar abnormalities seen in asthma include bronchiolar wall thickening, mucus stasis in bronchioles, and constrictive bronchiolitis (Fig. 4). Between clinical episodes, the bronchioles may be (nearly) normal when viewed in tissue collected for other reasons from asthmatic patients (Colby TV, personal observation). The high-resolution CT manifestations include areas of decreased attenuation and vascularity, air trapping, and small centrilobular opacities (Figs. 3 and 5).

Areas of decreased attenuation and vascularity are seen on high-resolution CT scans obtained at end-inspiration in approximately 20% of patients with asthma [1–3]. A more common finding on



A



B

Fig. 3.—52-year-old man with asthma and bronchiectasis.

A, High-resolution MDCT scan shows bilateral bronchiectasis (*straight arrows*) and areas of decreased attenuation and vascularity (*curved arrows*). Note that bronchi are dilated but are not thick-walled.

B, Coronal reformatted image shows ectatic bronchi and areas of decreased attenuation and vascularity in lower lobes (*arrows*) and normal upper lobes.

CT of Asthma and Associated Conditions

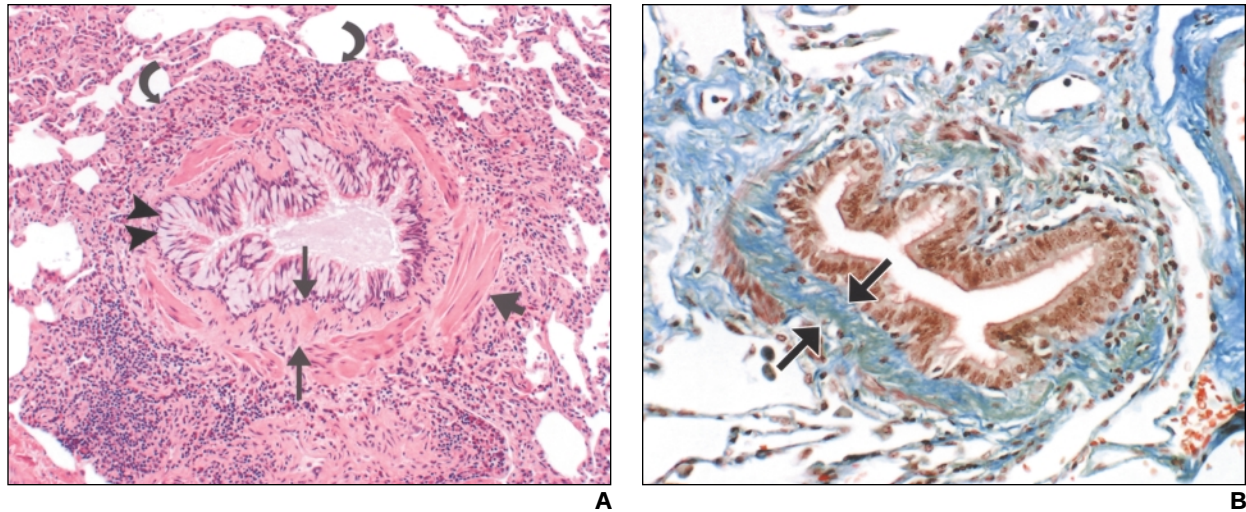


Fig. 4.—Bronchiolar abnormalities in two patients with asthma.

A, Photomicrograph of histopathologic specimen obtained in 10-year-old boy with fatal asthmaticus shows small bronchiole (outside diameter, 0.5 mm from adventitia to adventitia) with muscle hypertrophy (*short straight arrows*), submucosal and submembranous fibrosis (*long straight arrows*), and inflammatory infiltrate (*curved arrows*) rich in eosinophils. Goblet cell metaplasia (more typically seen in bronchi of patients with asthma) is prominent and seen as pale swollen cells (*arrowheads*) replacing much of columnar ciliated epithelium. Extent of submembranous and submucosal fibrosis (structural remodeling) is indicative of presence of mild constrictive bronchiolitis histologically. (H and E, intermediate magnification)
B, Photomicrograph of histopathologic specimen obtained in 48-year-old woman with long history of asthma shows bronchiole with submucosal thickening that was caused by fibrous tissue (*arrows*) and resulted in luminal narrowing. These findings are characteristic of mild constrictive bronchiolitis. (Trichrome stain, intermediate magnification)

CT scans obtained after maximal expiration is the presence of air trapping. In the study by Park et al. [3], air trapping involving a total volume equivalent to one pulmonary segment or more was seen in 50% of asthmatic patients compared with 14% of healthy subjects ($p < 0.001$).

Prominent centrilobular structures or small centrilobular opacities have been reported in 10–20% of patients with asthma [1, 2]. These presumably reflect the presence of mucus stasis in bronchioles or peribronchiolar inflammation.

Parenchymal Abnormalities

Parenchymal abnormalities in asthma include hyperinflation, emphysema, and, rarely, cysts. Hyperinflation is a common finding radiographically in patients with severe asthma, but emphysema is quite un-

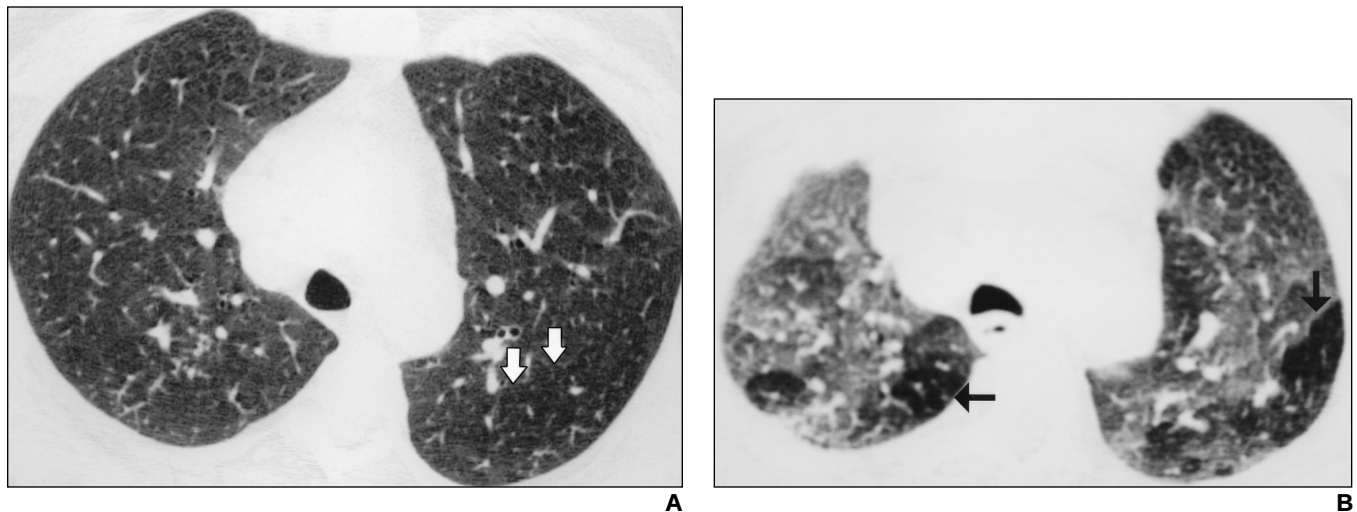


Fig. 5.—45-year-old woman with asthma and air trapping.

A, High-resolution CT scan obtained at level of aortic arch shows subtle areas (*arrows*) of decreased attenuation and vascularity.
B, High-resolution CT scan obtained at maximal expiration shows bilateral areas of air trapping with associated decrease (*arrows*) in vascularity. Presence of parenchymal abnormalities due to airway obstruction is much more readily seen on expiratory scan. Note invagination of posterior tracheal wall, which aids in identifying this as expiratory scan.

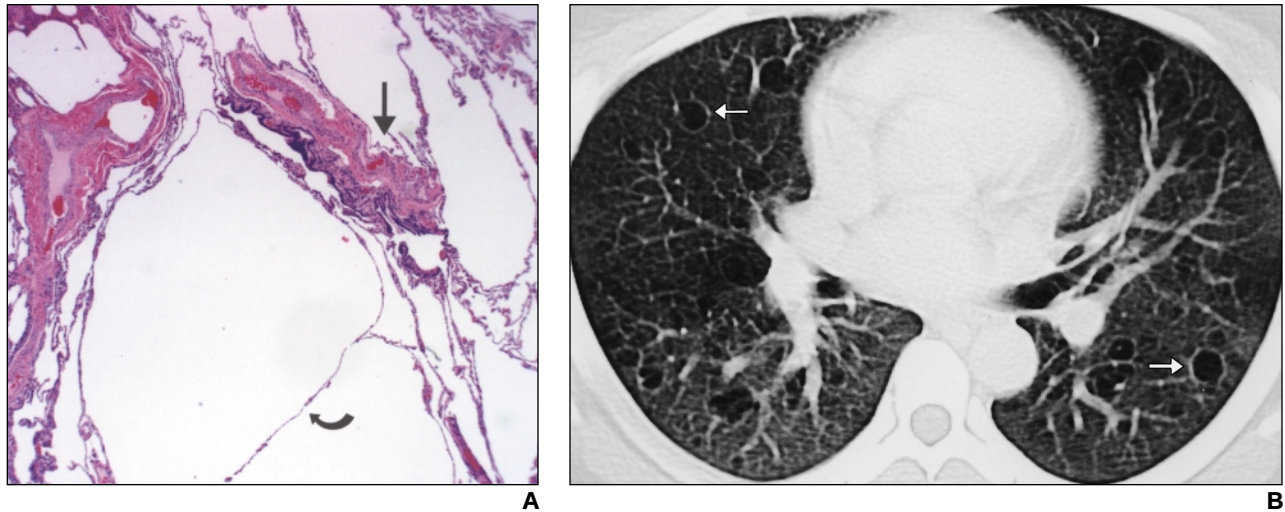


Fig. 6.—27-year-old woman with asthma and cystic changes. Patient had never smoked.
A, Photomicrograph of histopathologic specimen shows strand of residual alveolar tissue (curved arrow) remaining in cyst arising adjacent to bronchiole (straight arrow). (H and E, low magnification)
B, CT scan (5-mm collimation) shows bilateral small localized rounded areas of low attenuation (arrows) with well-defined smooth walls consistent with cysts, raising concerns of possible lymphangioleiomyomatosis. However, no evidence of lymphangioleiomyomatosis was found at surgical biopsy.

common. Lynch et al. [1] found evidence of emphysema in nine (19%) of 48 asthmatic patients compared with zero of 27 healthy control subjects. However, only two of the asthmatic patients with emphysema had never smoked. The diagnosis of emphysema in these patients was based on the presence of areas of abnormally low attenuation con-

sistent with emphysema on high-resolution CT of the chest [1]. Histologically, emphysema is uncommon in asthmatic nonsmokers; it is usually mild and secondary to cicatricial peribronchial fibrosis [4]. Rarely cystic changes may result from overinflating distal to chronic inflammatory bronchiolitis (Fig. 6).

High-Resolution CT and Histologic Manifestations of Associated Conditions

ABPA

ABPA is a clinical syndrome characterized by hypersensitivity reaction to endobronchial growth of *Aspergillus fumigatus*. The histologic findings, which vary from case to case, may include mucoid impaction of bronchi with

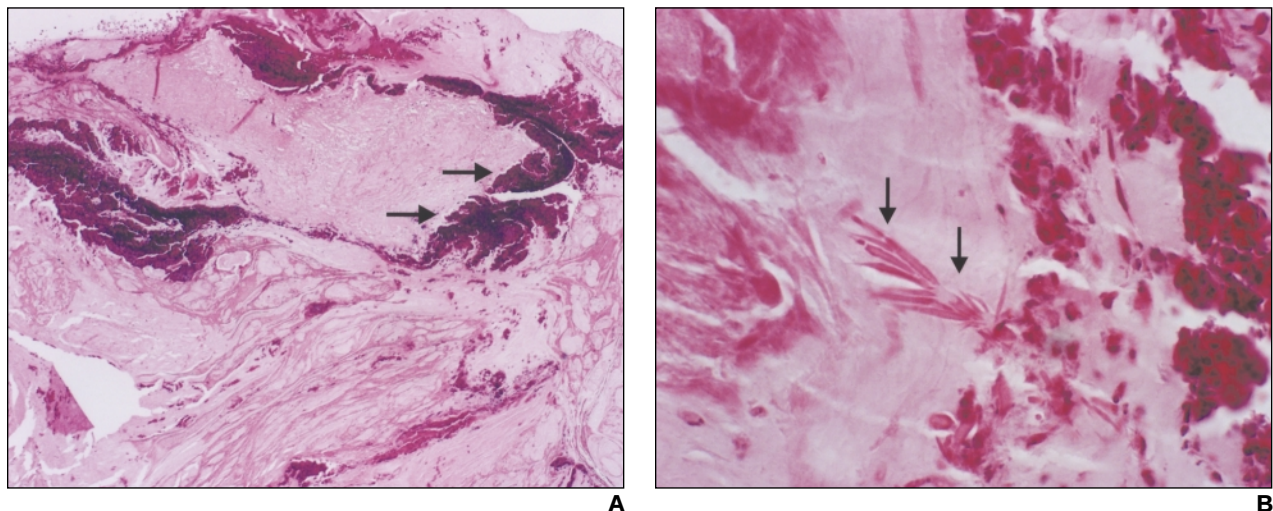
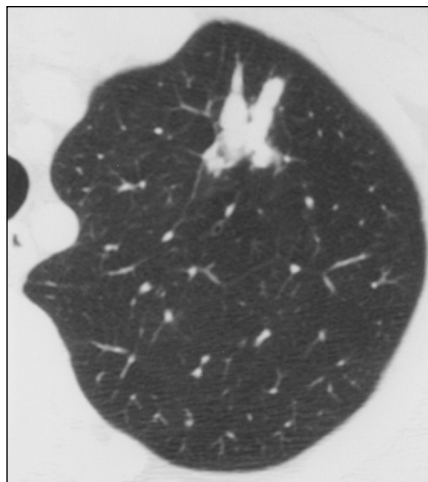


Fig. 7.—Histopathologic specimens of allergic bronchopulmonary aspergillosis (ABPA) obtained in 33-year-old woman with history of asthma. Diagnosis of ABPA was based on findings of this biopsy.
A, Photomicrograph shows sections of mucus plug with typical features of allergic mucin with layering of mucus and cell debris (arrows). (H and E, intermediate magnification)
B, Photomicrograph obtained with higher magnification than A shows that cell debris consists of degenerated eosinophils with associated Charcot-Leyden crystals (arrows). (H and E, high magnification)

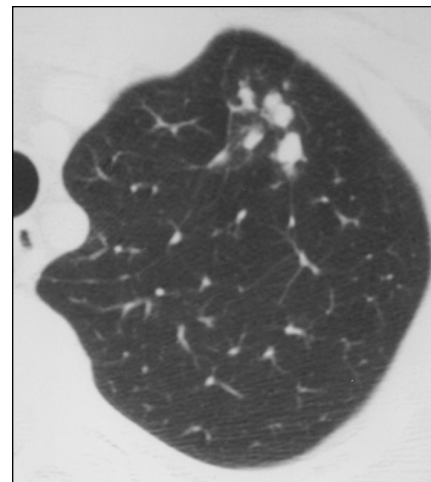
CT of Asthma and Associated Conditions

Fig. 8.—73-year-old woman with allergic bronchopulmonary aspergillosis.

A, High-resolution CT scan of left upper lobe shows branching opacities characteristic of mucoid impaction. **B,** High-resolution CT scan obtained at slightly higher level than **A** shows that mucoid impaction is present in several small bronchi.



A



B

the typical mucous plugs (allergic mucin) (Fig. 7), bronchocentric granulomatosis, bronchiectasis, and eosinophilic pneumonia [4]. These patients also typically have positive results on skin tests and markedly elevated serum levels of immunoglobulin E (IgE) levels. Bronchocentric granulomatosis often occurs in patients with ABPA. It is characterized by a pattern of necrotizing granulomatous inflammation that destroys the walls of small bronchi and bronchioles [4].

The high-resolution CT manifestations of ABPA include homogeneous tubular, finger-in-glove, or branching endobronchial opacities and bronchiectasis involving mainly the segmental and subsegmental bronchi of the upper lobes (Figs. 8–10). In approximately 30% of

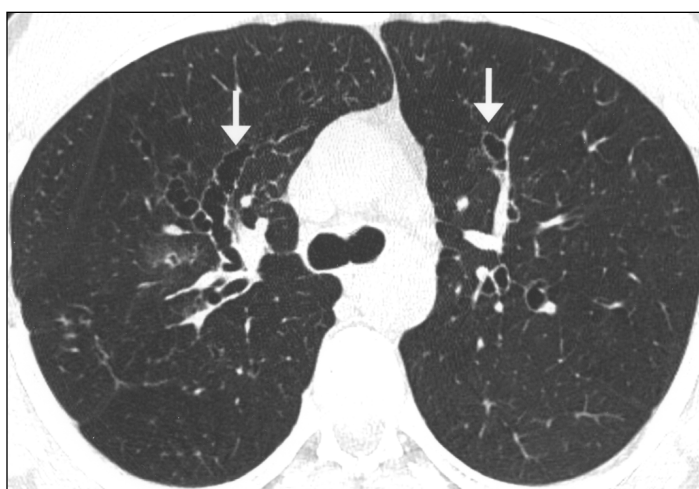
patients with ABPA, the impacted mucus exhibits attenuation greater than that of soft tissue, consistent with calcification. The mucus plugging can extend into bronchioles resulting in centrilobular nodular opacities [4] (Fig. 10).

Ward et al. [6] compared the high-resolution CT findings in 44 asthmatic patients with ABPA and 38 asthmatic patients without ABPA. Abnormalities seen more commonly in patients with ABPA included bronchiectasis, centrilobular nodules, and mucoid impaction ($p < 0.01$). Bronchiectasis was present in 95% of patients with ABPA; centrilobular nodules, in 93%; and mucoid impaction, in 67%. By comparison, bronchiectasis was detected in 29% of the asthmatic control group; centrilobular nodules, in

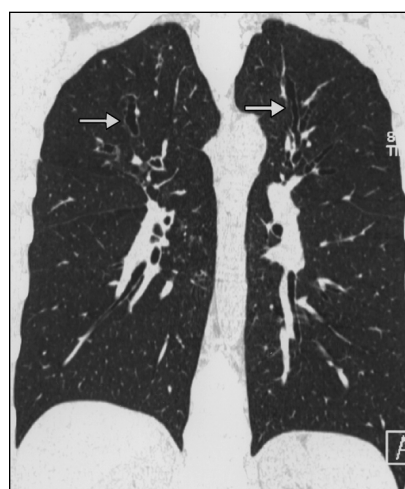
28%; and mucoid impaction, in 4% [6]. Mitchell et al. [5] compared the high-resolution CT scans obtained in 19 patients with documented ABPA with scans obtained in 18 asthmatic control subjects. Seventeen patients (89%) with ABPA had central cystic or varicose bronchiectasis typically involving several lobes. By comparison, only three asthmatic patients (17%) had bronchiectasis, and it was exclusively cylindrical in nature [5].

Chronic Eosinophilic Pneumonia

Chronic eosinophilic pneumonia is a condition characterized histologically by the presence of intraalveolar eosinophils, macrophages, an amorphous proteinaceous exudate, and



A

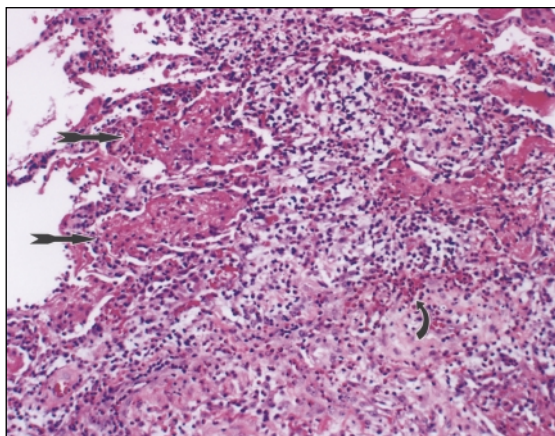
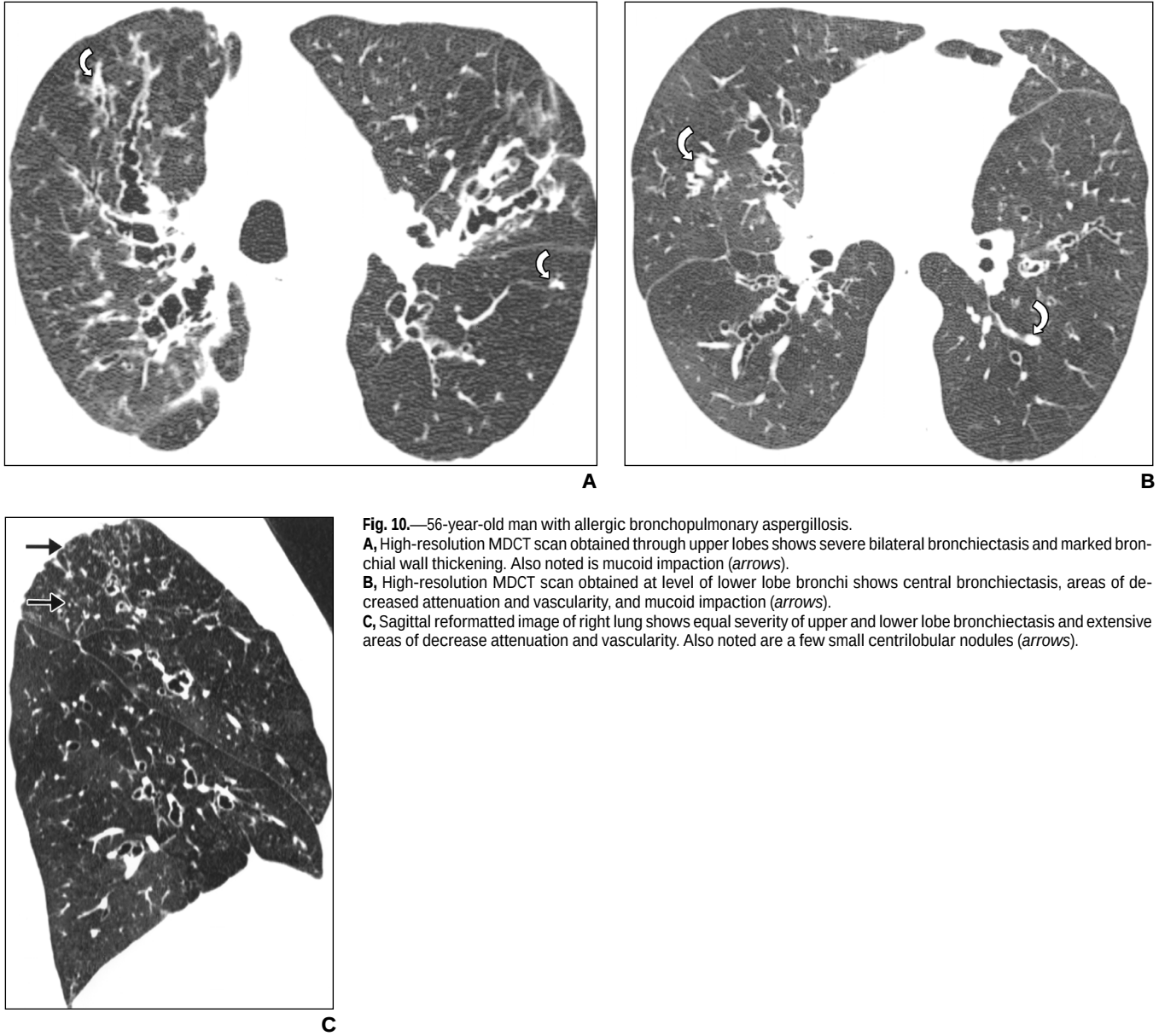


B

Fig. 9.—32-year-old woman with allergic bronchopulmonary aspergillosis.

A, High-resolution MDCT scan obtained shows central varicose bronchiectasis (arrows) in both upper lobes.

B, Coronal reformatted image shows varicose bronchiectasis (arrows) in upper lobe and normal bronchi in lower lobe.



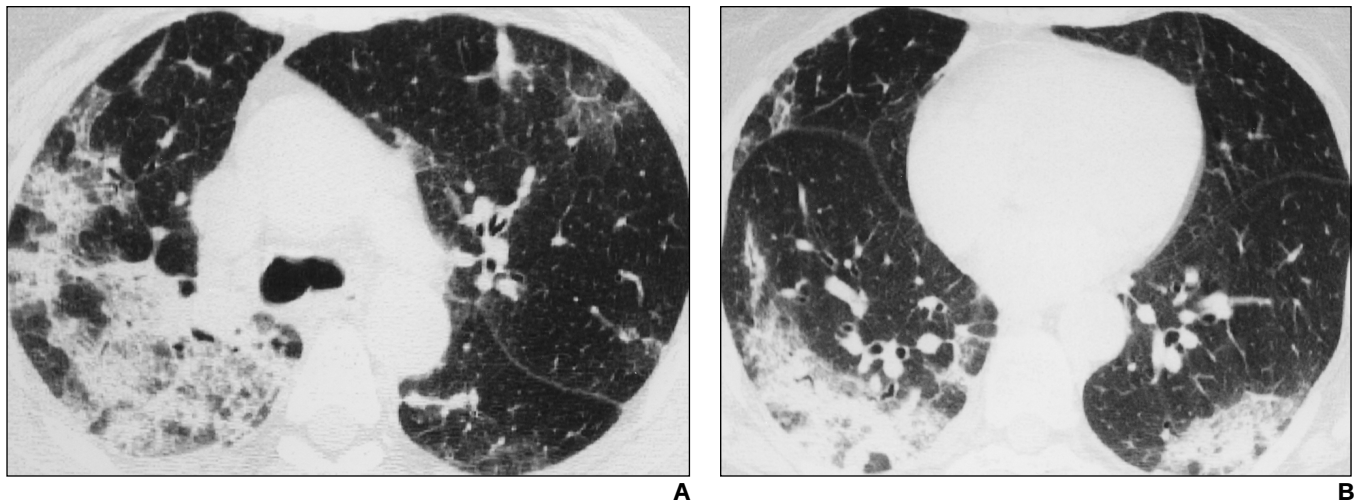


Fig. 12.—75-year-old woman with chronic eosinophilic pneumonia.

A, High-resolution CT scan obtained at level of main bronchi shows extensive consolidation in right upper lobe and small localized areas of ground-glass attenuation and consolidation in left upper lobe.

B, High-resolution CT scan obtained at level of lower lung zones shows consolidation exclusively in peripheral lung regions.

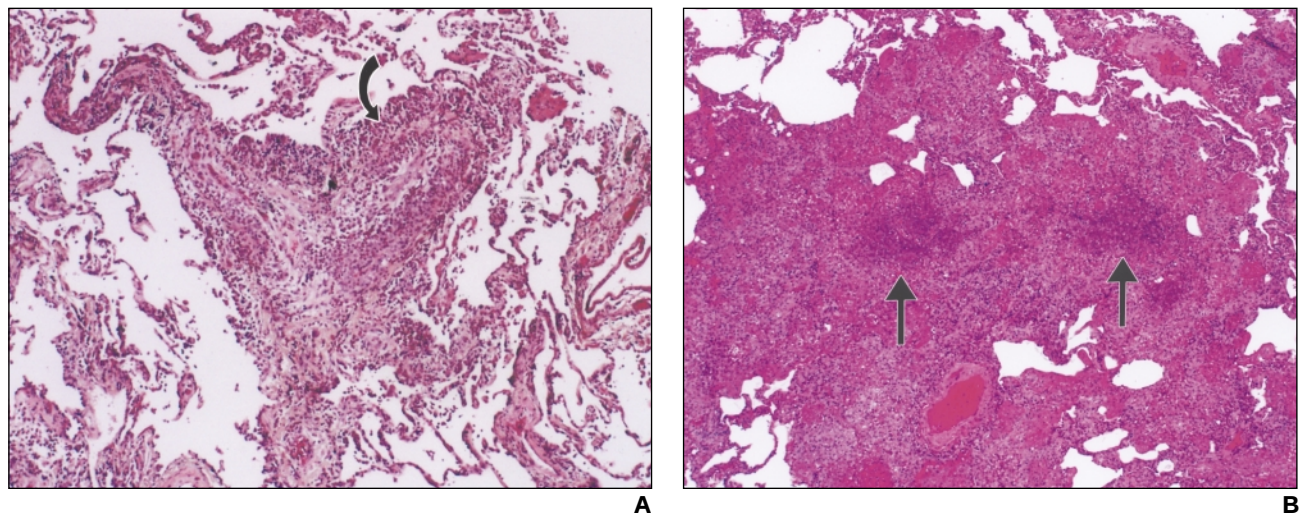


Fig. 13.—Histopathologic findings of Churg-Strauss syndrome in two patients.

A, Photomicrograph of pathologic specimen obtained in 67-year-old woman shows vasculitis (arrow) involving small vessel at its branch point. Transmural inflammatory infiltrate was mixed in composition, with histiocytes, lymphocytes, and numerous eosinophils that are just barely discernible. (H and E, intermediate magnification)

B, Photomicrograph of pathologic specimen obtained in 50-year-old man shows areas of consolidation and early necrosis (arrows) that primarily represented degenerating eosinophils. Inflammatory interstitial and air-space infiltrate is mixed in composition, and resulting consolidation obscures underlying architecture of lung. (H and E, intermediate magnification)

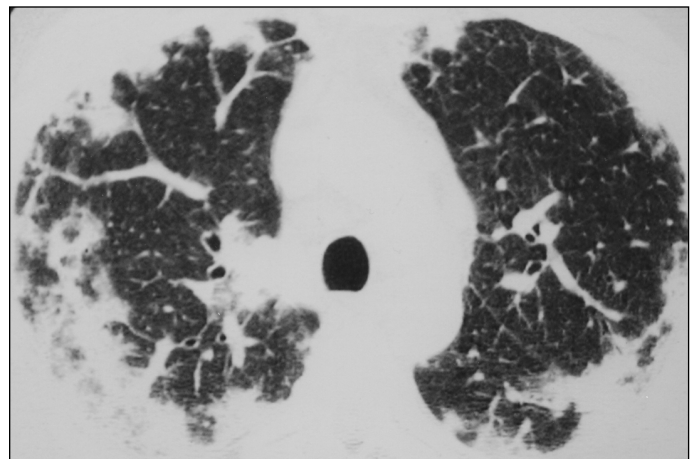


Fig. 14.—52-year-old man with Churg-Strauss syndrome. High-resolution CT scan obtained at level of aortic arch shows bilateral focal areas of peripheral consolidation. Appearance is identical to that of chronic eosinophilic pneumonia or bronchiolitis obliterans with organizing pneumonia.

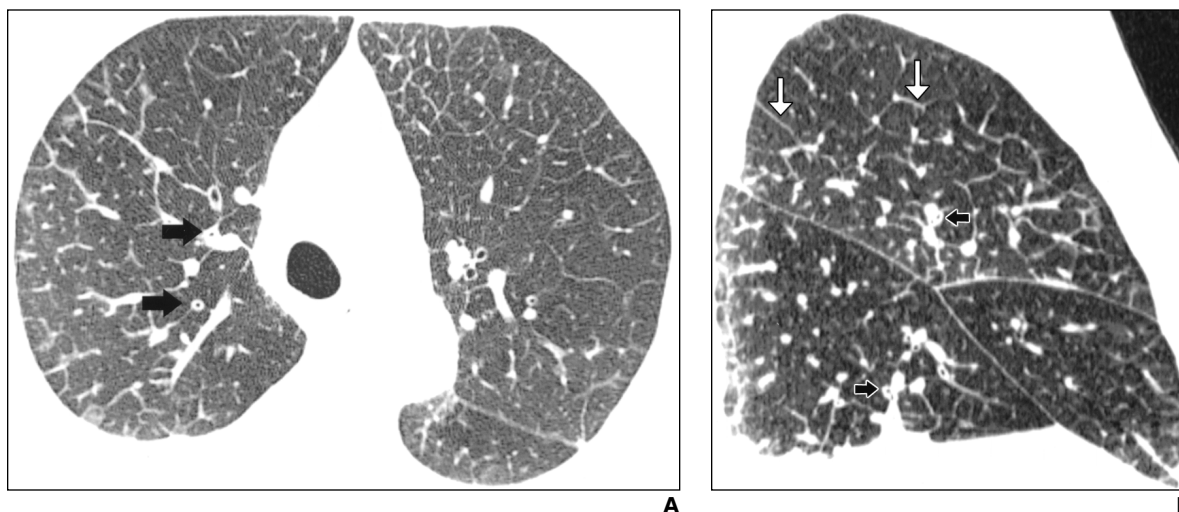


Fig. 15.—68-year-old woman with Churg-Strauss syndrome.

A, High-resolution MDCT scan obtained at level of upper lobes shows extensive bilateral septal thickening. Also noted are bronchial wall thickening (arrows), small peripheral ground-glass opacities, and a small right pleural effusion.

B, Sagittal reformatted image of right lung shows septal thickening predominately in upper lobe (white arrows) and in dorsal regions of lower lobe. Also noted is extensive bronchial wall thickening (black arrows).

organizing pneumonia (Fig. 11). The organizing pneumonia can be associated with intraluminal organization in bronchioles (bronchiolitis obliterans with organizing pneumonia). The patients present clinically with fever, night sweats, cough, and dyspnea. Most patients have peripheral eosinophilia. Approximately 50% of patients are asthmatics; women are affected twice as frequently as men. The characteristic radiologic manifestations consist of bilateral areas of consolidation mainly affecting the peripheral regions of the middle and upper lung zones (Fig. 12). The predominantly peripheral distribution of the consolidation is evident on radiography in approximately 65% of patients and on high-resolution CT in 95% of patients [7].

Churg-Strauss Syndrome

Churg-Strauss syndrome is a multisystem disorder characterized by the combination of allergy, peripheral blood eosinophilia, and systemic vasculitis (Fig. 13). Almost all patients with Churg-Strauss syndrome are asthmatics, and most present with peripheral neuropathy, typically mononeuritis multiplex. The histologic findings consist of a necrotizing vasculitis of medium- to small-sized blood vessels associated with eosinophilic infiltration around

the vessels and adjacent tissues. Common sites of involvement include the lungs, heart, kidneys, and skin.

The most common high-resolution CT findings consist of patchy nonsegmental bilateral areas of consolidation or ground-glass opacities that often have a predominately peripheral distribution characteristic of chronic eosinophilic pneumonia [8] (Fig. 14). Less common manifestations include multiple solid or cavitated 1- to 3-cm-diameter pulmonary nodules, small centrilobular nodules, and interlobular septal thickening (Fig. 15). The interlobular septal thickening may result from pulmonary eosinophilic infiltration or the presence of pulmonary edema due to cardiac involvement. Histologically, the infiltrates and nodules in Churg-Strauss syndrome show varying degrees of inflammatory consolidation, rich in eosinophils (including eosinophilic pneumonia), granulomatous reaction, vasculitis, and necrosis. Necrosis may be punctate and surrounded by giant cells (the Churg-Strauss granuloma) or much more extensive and predominantly composed of necrotic eosinophils.

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