# Pictorial Essay

# Expiratory Chest CT in Children

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Expiratory chest CT can improve recognition of anomalies not seen on inspiratory examinations [1]. Whenever we study cooperative patients with clinical features or CT findings suggestive of air trapping, we complete the examination with three expiratory slices: one in the upper, one in the middle, and one in the lower third of the chest. A useful method of obtaining expiratory CT scans in patients not following breath-holding commands is to use the lateral decubitus technique, which Capitanio and Kirkpatrick [2] describe for conventional chest radiography. When the child is placed on one side, the dependent hemithorax will be on expiration and the hemithorax facing up will be on inspiration (Fig. 1). This method can be applied to perform expiratory or inspiratory chest CT scans. When air trapping is suspected, we image one or two slices of the suspicious portion of the lung with the patient in the lateral decubitus position. If air trapping is present, the dependent lung, lobe, or segment will remain hyperlucent (Fig. 2). In this pictorial essay, we review the chest CT features of several pediatric lung disorders in which expiratory radiographs provide information of diagnostic value.

### Congenital Malformations

Air trapping is a common feature in several pulmonary malformations. Type I or type II cystic adenomatoid malformations usually present multiple thin-walled air- or fluid-filled cysts [3]. These lesions will often present air trapping on expiration and will, therefore, be easier to detect with expiratory scans (Fig. 3).

Bronchial atresia, which most frequently involves the left upper lobe, obviously impedes ventilation of the affected part of the lung. Chest CT will usually show hyperexpansion of the affected lobe with some central densities corresponding to mucoceles. Occasionally, air- or air-and-fluid–filled cysts or tubular densities or both will be seen [4]. Expiratory examinations facilitate identification of the air trapping distal to the atretic bronchus (Fig. 4).

An appearance simulating emphysema can be seen in pulmonary sequestration. It has been suggested that this appearance results from collateral ventilation and air trapping [5] (Fig. 5). Lobar emphysema usually presents on the radiograph as overdistended upper or right middle lobes. An expiratory CT scan is helpful in delineating the extent of the malformation (Fig. 6).

### Bronchiolitis Obliterans

Bronchiolitis obliterans is a lung disease characterized by granulation tissue that may lead to extensive scarring and obliteration of the small airways [6]. In children most cases of bronchiolitis obliterans are of infectious origin and occur after pulmonary infections by adenovirus, measles, pertussis, tuberculosis, and mycoplasma. Other causes include toxic gas inhalation, connective tissue disease, drug reaction, and chronic graft-versus-host disease in patients after transplantation [7]. A mosaic perfusion pattern of lung attenuation, air trapping, peribronchial thickening, and bronchiectasis is the most common CT feature of

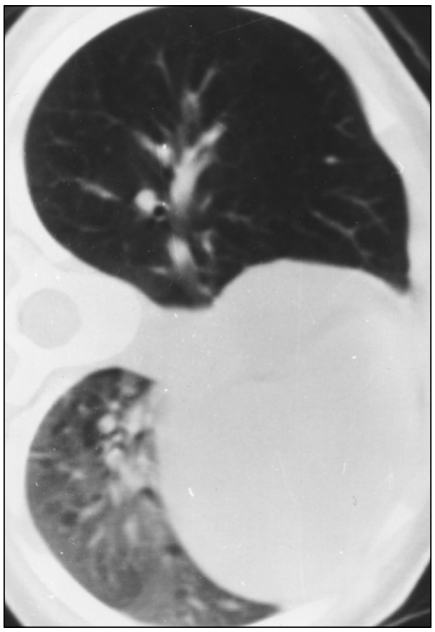

**Fig. 1.**—12-month-old girl with previous episodes of bronchiolitis. CT scan with patient in left lateral decubitus position shows normal findings. When left lung is in full expiration, right lung is well aerated.

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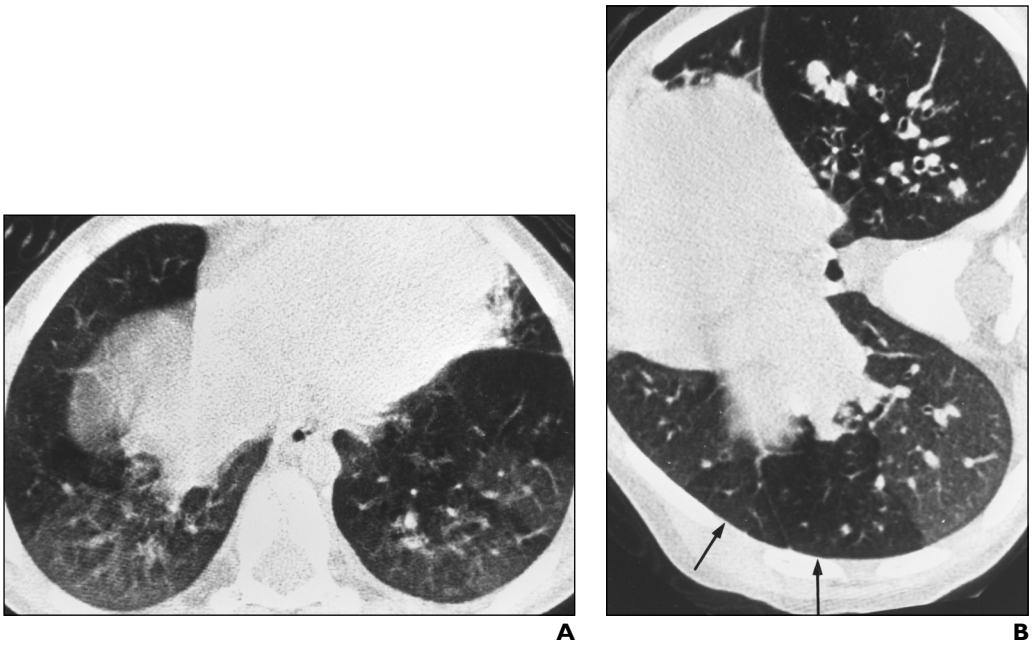



**Fig. 2.**—4-year-old boy with immunodeficiency and repeated episodes of left lower lobe pneumonia.
**A**, Inspiratory CT scan with patient supine shows mosaic perfusion pattern in both lower lobes and questionable bronchiectasis in left lower lobe.
**B**, Right lateral decubitus chest CT scan at same level as **A** confirms air trapping in right middle and lower lobes (*arrows*) and improves depiction of left lower lobe bronchiectasis.

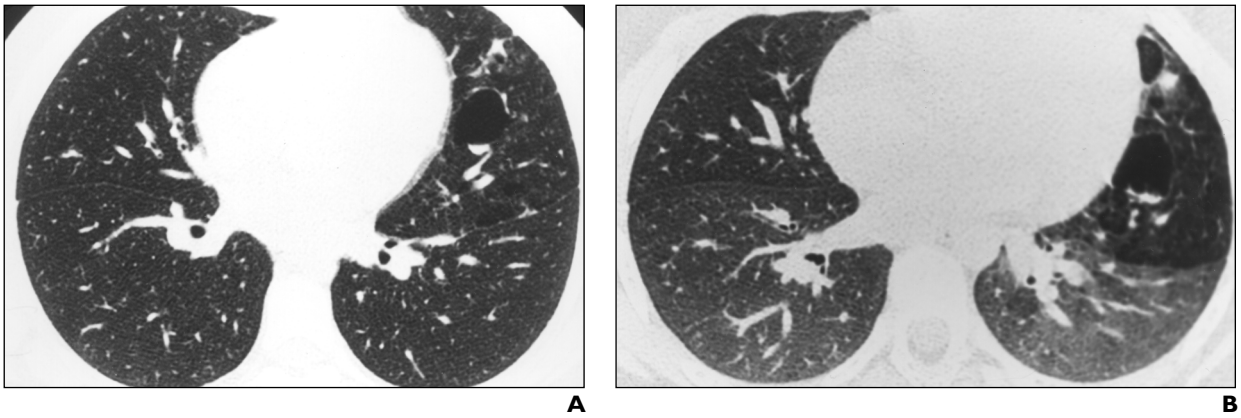



**Fig. 3.**—8-year-old girl with cystic adenomatoid malformation type II.
**A**, Inspiratory CT scan shows several thin-walled left upper lobe cysts.
**B**, Expiratory CT scan at same level as **A** better reveals cysts and border of lesion on expiration.

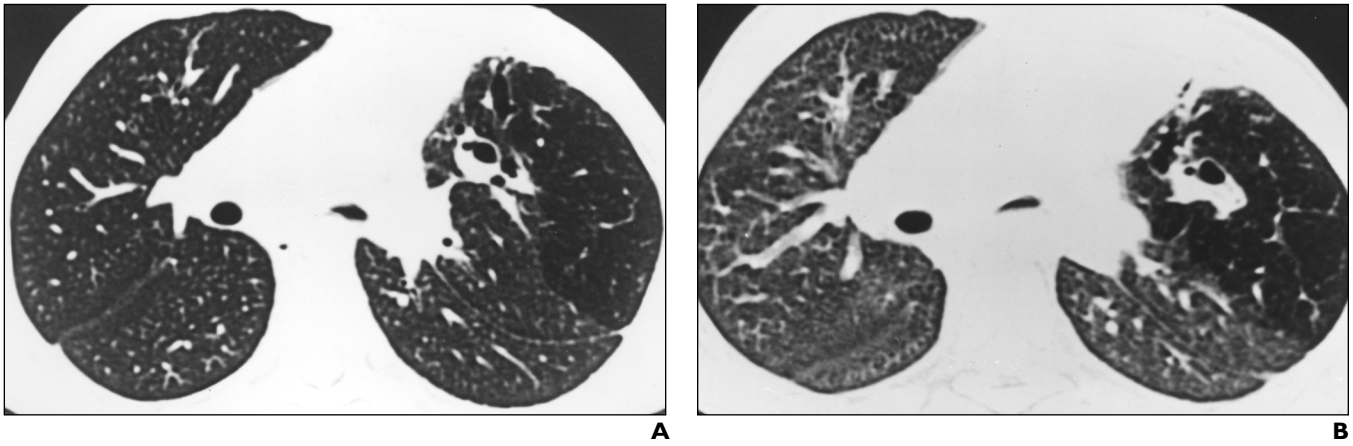



**Fig. 4.**—7-year-old boy with left upper lobe bronchial atresia.
**A**, Inspiratory CT scan shows dilated mucous- and air-filled bronchi and peripheral emphysema.
**B**, Expiratory CT scan at same level as **A** shows significant air trapping and improved delineation of borders of malformation.

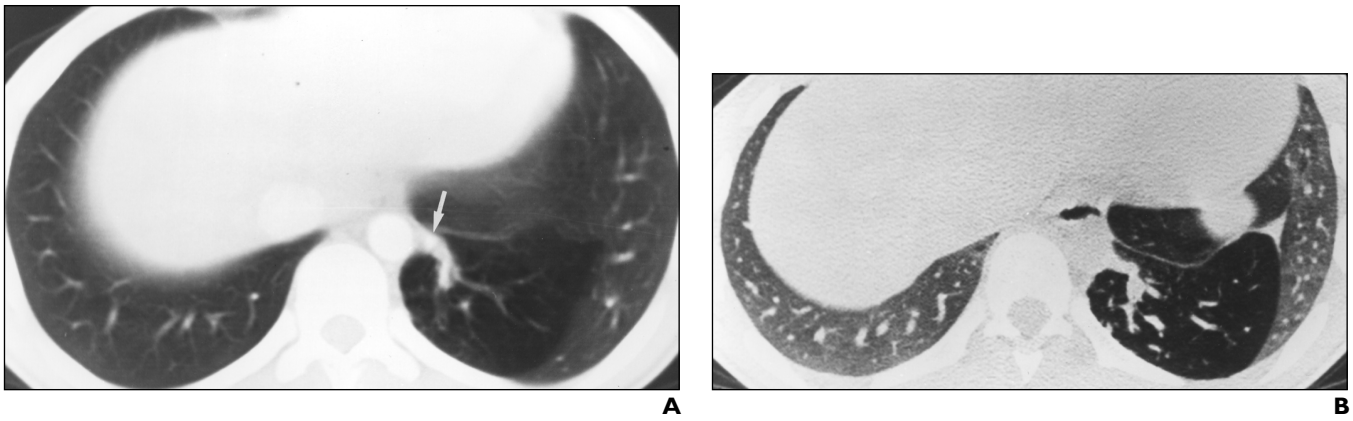



**Fig. 5.**—15-year-old boy with intralobar pulmonary sequestration in left lower lobe.
**A**, Enhanced CT scan shows hyperlucency in left lower lobe. Systemic vessel (*arrow*), originating from aorta and feeding sequestration, is well defined.
**B**, Expiratory high-resolution CT scan at same level as **A** shows significant air trapping within sequestered lung.

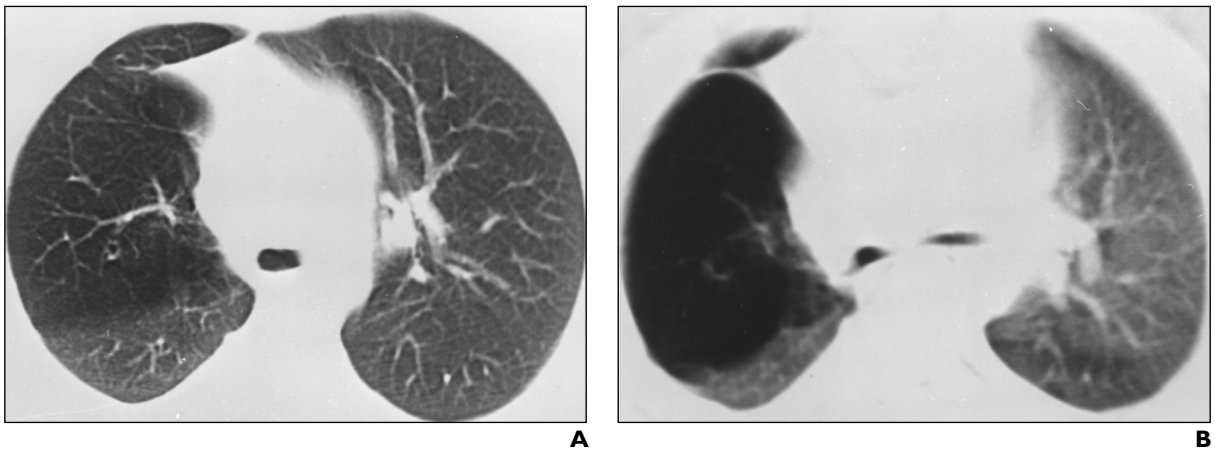



**Fig. 6.**—9-year-old asymptomatic boy with long-standing lobar emphysema of right upper lobe.
**A**, Inspiratory CT scan shows right upper lobe emphysema.
**B**, Expiratory CT scan at same level as **A**. Emphysema is better delineated. Note decreased vascularity of affected lobe. This finding, seen on inspiratory or expiratory scans, should suggest that associated emphysema is obstructive rather than compensatory.

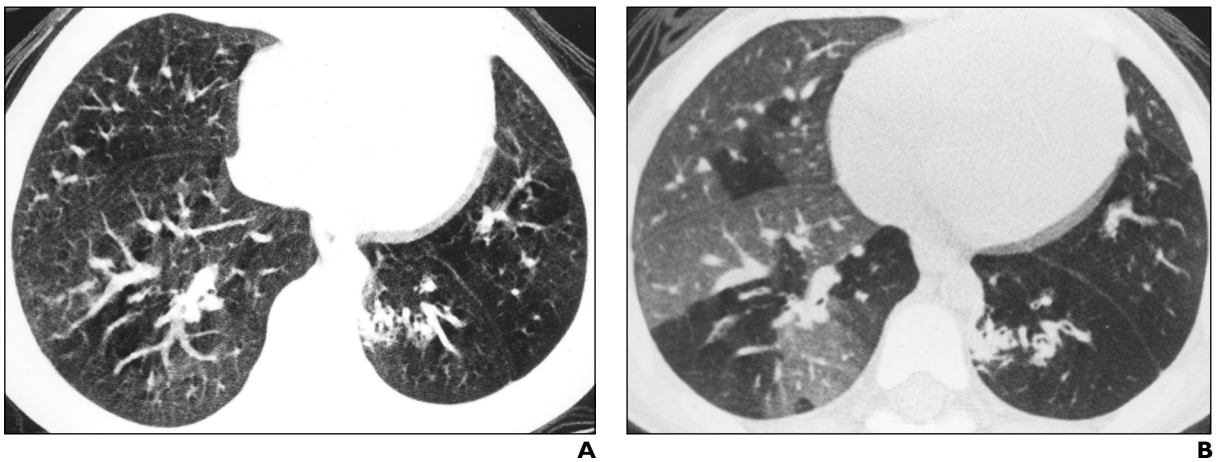



**Fig. 7.**—6-year-old boy with postinfectious bronchiolitis obliterans.
**A**, Inspiratory CT scan shows hyperlucent left lung with left lower lobe bronchiectasis and mosaic perfusion pattern of lung attenuation in both lungs.
**B**, Expiratory CT scan at same level as **A**. Bilateral patchy air trapping is clearly visible.

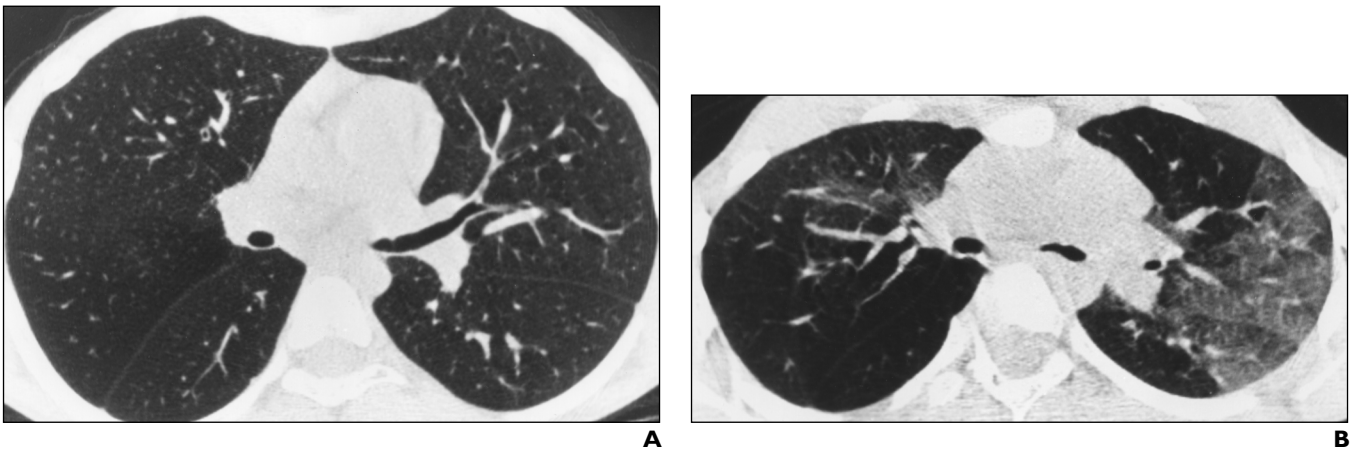


**Fig. 8.**—9-year-old boy with bronchiolitis obliterans after infection.
**A**, Inspiratory CT scan shows hyperlucent right upper and lower lobes. Left lung appears normal.
**B**, Expiratory CT scan at same level as **A**. Bilateral patchy air trapping is well identified.

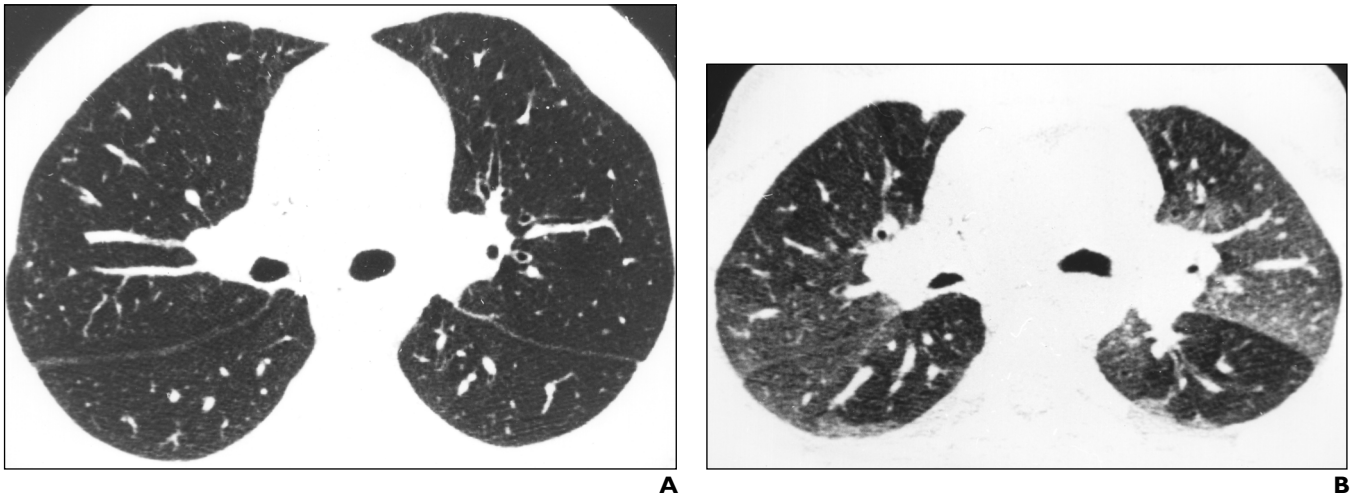


**Fig. 9.**—11-year-old girl with cystic fibrosis. Chest CT scans performed 6 months after bilateral lung transplantation.
**A**, Inspiratory CT scan shows no significant abnormalities.
**B**, Expiratory CT scan at same level as **A** shows mosaic perfusion pattern. This pattern is common CT finding in children after lung transplantation and, although it may be seen in asymptomatic patients, should be regarded as suggestive of bronchiolitis obliterans.

bronchiolitis obliterans. Expiratory chest CT can improve the detection of this disease (Figs. 7–9). Furthermore, it may reveal bilateral pulmonary involvement where chest radiographs and inspiratory CT scans had shown unilateral disease (Figs. 8 and 9).

### Asthma and Reactive Airways Disease

Asthma is usually diagnosed on the basis of clinical findings, and high-resolution CT (HRCT) is not indicated. Sometimes children with asthma will present with recurrent bouts of pulmonary infection, and HRCT will be requested to show or rule out predisposing pulmonary abnormalities. Common CT findings in asthma include bronchial wall thickening, cylindric bronchiectasis, small centrilobular opacities, a mosaic perfusion pattern of lung attenuation, mucoid impaction, and right middle lobe collapse. Expiratory HRCT can show air trapping in asthma patients who have normal findings on inspiratory scans (Fig. 10). Contrary to what occurs in patients with bronchiolitis obliterans, these areas of air trapping can completely disappear on CT scans obtained after therapy with bronchodilators.

### Bronchiectasis

HRCT is more sensitive than unenhanced radiography or conventional CT scans and is the imaging technique of choice for the diagnosis of bronchiectasis. Airway obstruction distal to classic postinfectious bronchiectasis is extremely common; therefore, areas of pulmonary hyperexpansion with air trapping on expiration will almost always be seen in the lobes harboring the bronchiectasis [8]. Sometimes, when interpreting the HRCT scans, one may doubt whether some of the visualized linear densities correspond to normal vascular structures or to mucous-filled dilated bronchi. In such instances, identification of associated air trapping will favor the diagnosis of bronchiectasis (Fig. 11). In the follow-up HRCT scans of patients with cylindric bronchiectasis responding to long-term therapy, it is not unusual to observe persistent areas of air trapping on expiration

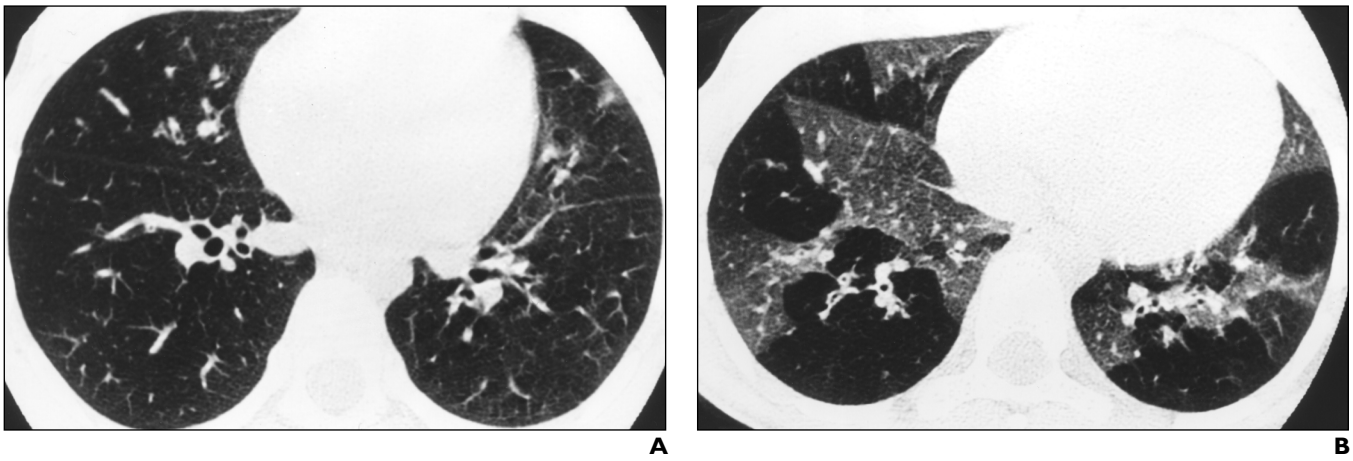



**Fig. 10.**—4-year-old girl with asthma.
**A**, Inspiratory CT scan shows subtle bilateral mosaic perfusion pattern of lung attenuation.
**B**, Expiratory CT at same level as **A** reveals patchy areas of air trapping.

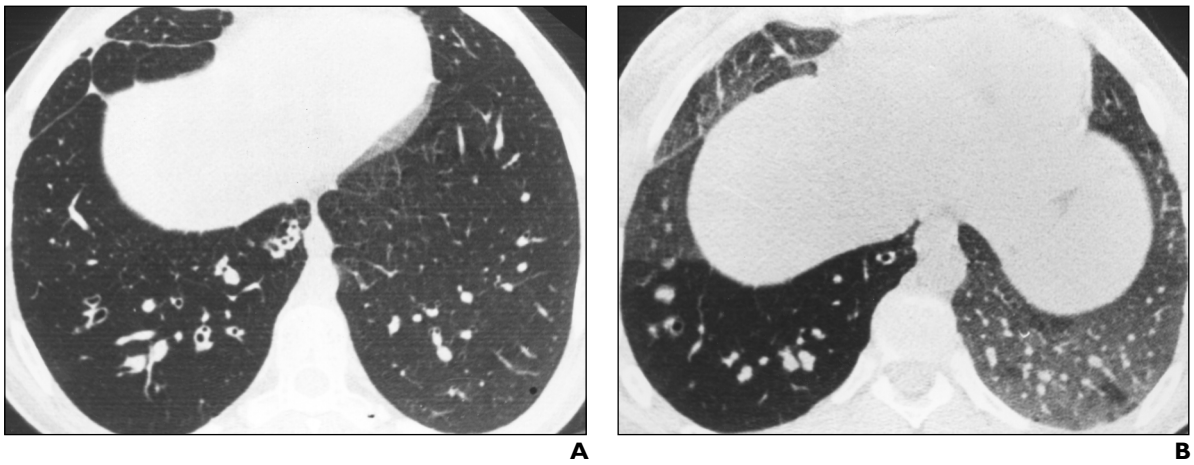



**Fig. 11.**—13-year-old girl with right lower lobe bronchiectasis.
**A**, Inspiratory CT scan shows bronchiectasis and subtle hypoattenuation in right lower lobe.
**B**, Expiratory CT scan at same level as **A** shows air trapping in affected lobe.

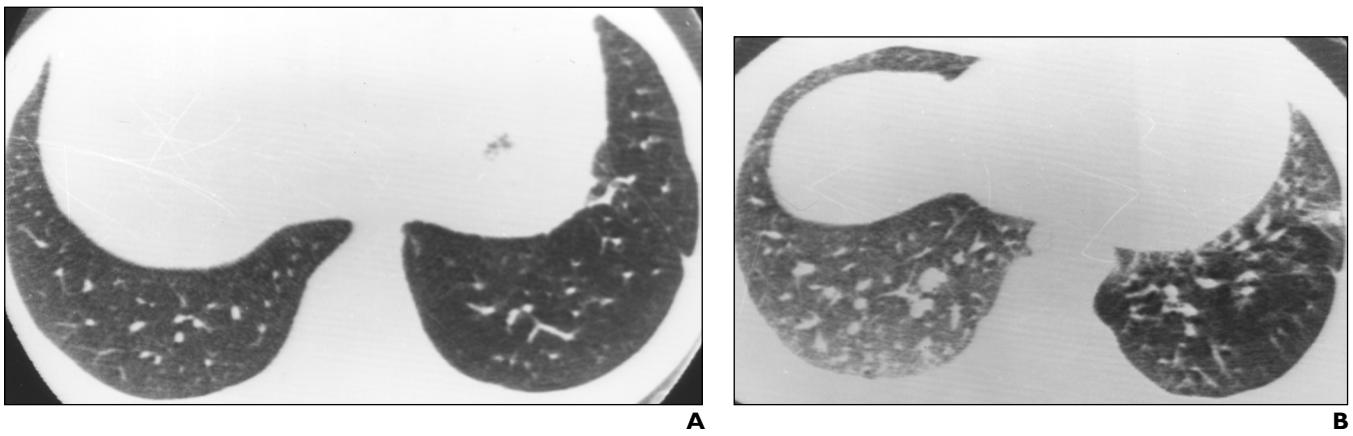
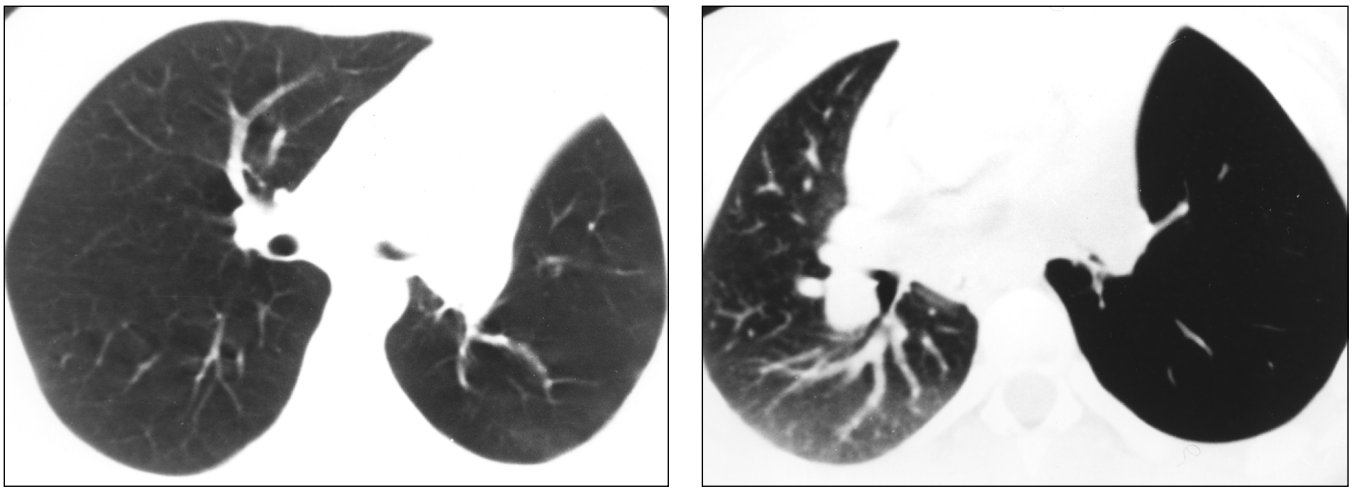



**Fig. 12.**—11-year-old boy with left lower lobe bronchiectasis treated with long-term antibiotics and physiotherapy. Patient was clinically well.
**A**, Inspiratory CT scan shows slight hypoattenuation of left lower lobe.
**B**, Expiratory CT scan at same level as **A** shows significant air trapping.



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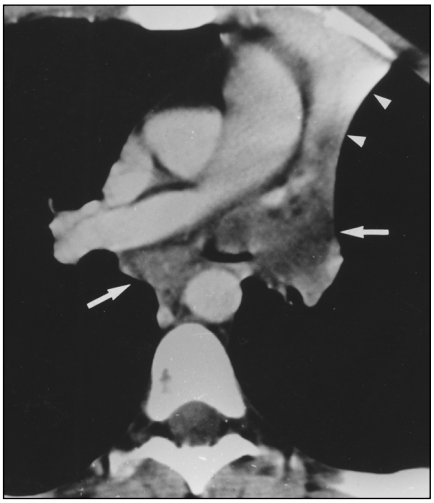

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**Fig. 13.**—12-year-old girl with neuroectodermal tumor of right thigh that had been treated with chemotherapy. One year after initial diagnosis, she developed chest pain. Unenhanced radiograph (not shown) showed left upper lobe collapse.
**A**, Chest CT scan shows left upper lobe collapse and increased hypoattenuation of left lower lobe. Reduced number of vessels in left lower lobe suggests obstructive emphysema.
**B**, Expiratory chest CT scan reveals obstructive emphysema of left lower lobe.
**C**, Mediastinal contrast-enhanced chest CT scan shows multiple mediastinal lymph nodes (*arrows*) completely obstructing left upper lobe and partially obstructing left lower lobe bronchi. Note significant enhancement of collapsed left upper lobe *(arrowheads*).

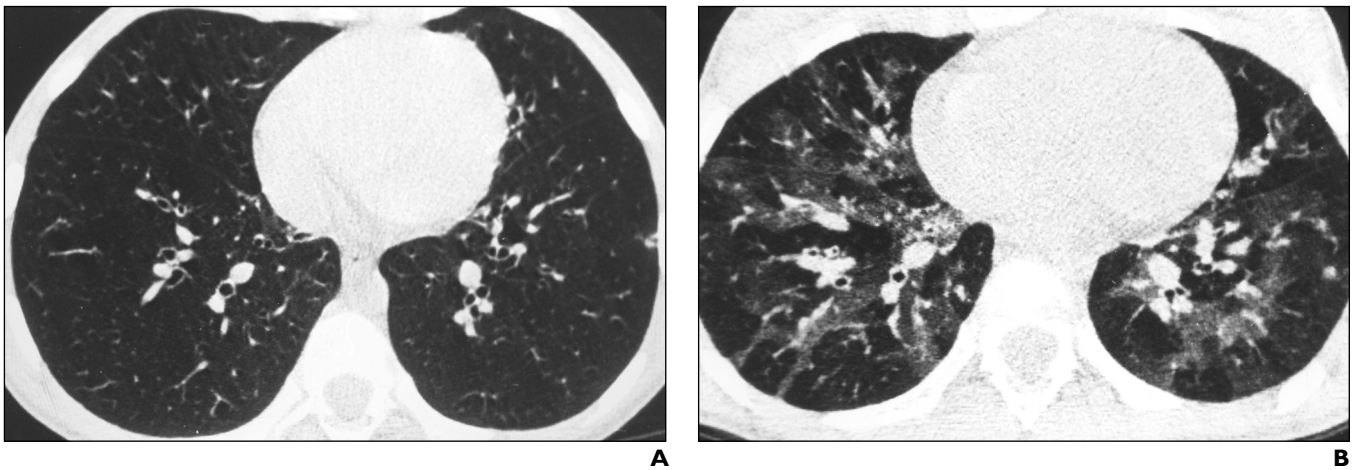

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**Fig. 14.**—11-year-old girl with cystic fibrosis.
**A**, Inspiratory CT scan shows mild peribronchial thickening.
**B**, Expiratory CT scan at same level as **A** reveals significant patchy air trapping.

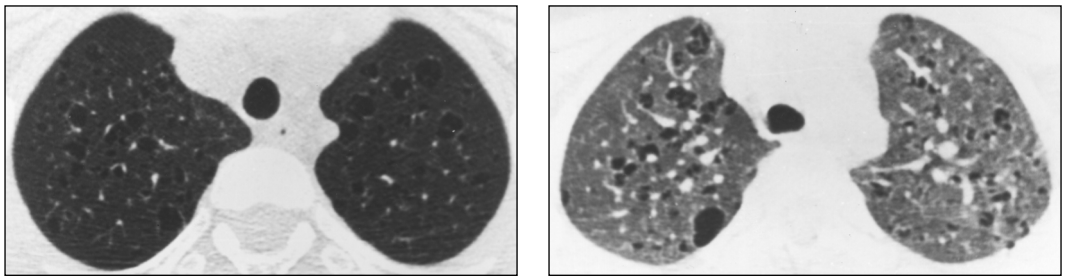

**Fig. 15.**—11-year-old boy with Langerhans' cell histiocytosis. **A**, Inspiratory CT scans show multiple thin-walled cysts. **B**, Expiratory CT scan at same level as **A** better reveals number and borders of cysts.

long after the previous bronchiectasis has become unidentifiable (Fig. 12).

### Mediastinal Masses

Some mediastinal masses, particularly those located in the middle mediastinum, can compress the adjacent bronchi and, depending on the degree of bronchial obstruction, cause either pulmonary collapse or obstructive emphysema (Fig. 13). One or two expiratory CT slices of the suspected site may reveal the presence of obstructive emphysema, suspected with inspiratory scans. Expiratory slices should not be obtained routinely.

### Systemic Diseases

#### *Cystic Fibrosis*

HRCT provides more information than conventional radiographs. We usually examine patients with cystic fibrosis with limited-slice low-dose HRCT. One of the earliest HRCT findings in cystic fibrosis is the presence of sharply defined lobular areas of decreased attenuation, presumably representing lobular or subsegmental air trapping, which can be seen only on expiratory HRCT scans (Fig. 14). Other early findings include peribronchial thickening, bronchiectasis, and bronchiolar impaction or "tree-in-bud."

#### *Langerhans' Cell Histiocytosis*

Langerhans' cell histiocytosis of the lung is an idiopathic disease usually occurring in children and young adults. In most patients, HRCT scans show peribronchial and centrilobular nodules of 1–5 mm in diameter or air-filled thin-walled cysts that are usually smaller than 10 mm in diameter or both. Because the normal lung becomes dense on expiration, expiratory slices can facilitate visualization of small cysts (Fig. 15).

In our experience additional expiratory slices should only be obtained in cases in which the radiologist thinks such slices can provide information not clearly depicted on the routine CT scans. To minimize the radiation dose, we usually obtain these slices using a low-milliamperage (34–50 mAs) HRCT technique.

### Acknowledgment

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