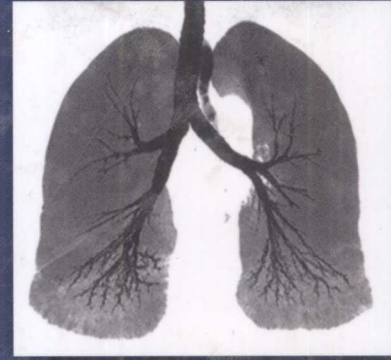
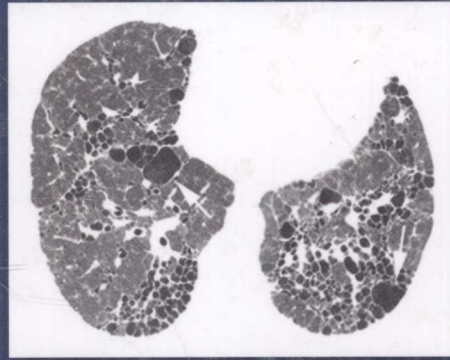
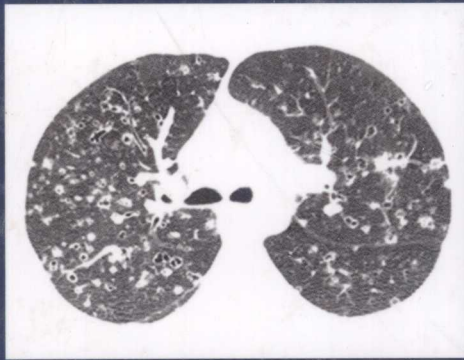


HIGH-RESOLUTION CT

of the LUNG

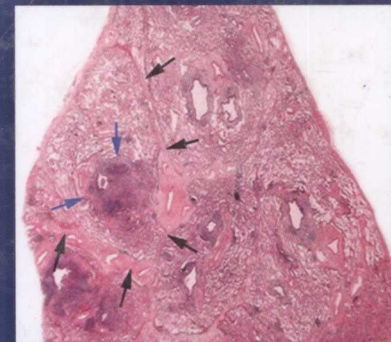
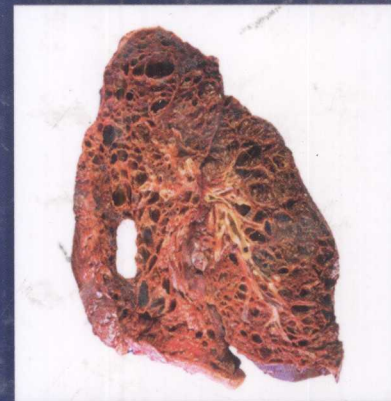
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W. Richard Webb

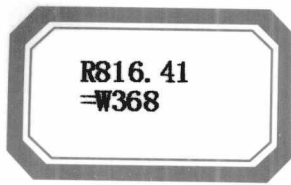
Nestor L. Müller

David P. Naidich



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High-Resolution CT of the Lung

FOURTH EDITION

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Preface

Since the late 1980s, high-resolution CT (HRCT) has become established as an indispensable tool in the evaluation of patients with suspected diffuse pulmonary disease. It is commonly used in clinical practice to detect and accurately characterize a variety of lung abnormalities. In the years since the third edition was published, considerable progress has occurred in the understanding of diffuse lung diseases, as well as their nature, causes, and characteristics. Without a doubt, HRCT has played a significant role in allowing this progress to occur.

In this edition, we incorporate an update and review of recent advances in the classification and understanding of diffuse lung diseases and their HRCT features. In keeping with this, we provide chapters that review specific disease categories, rather than group diseases on the basis of HRCT findings. We expand our discussion and illustrations to include enhanced descriptions of normal anatomy, HRCT findings, and diseases not covered in our earlier editions, and provide additional examples of disease entities we have shown previously. In the case of common and uncommon diseases alike, we attempt to illustrate the range of abnormalities that may be encountered in clinical

practice. We also add color to better illustrate the anatomical and pathological correlates of HRCT findings in specific diseases. Recent technical advances in obtaining HRCT are also reviewed, most notably the use of multidetector HRCT. It is hoped that the reader finds these changes helpful.

At the same time, we retain features that have proven popular with readers, including a description of the types of abnormalities seen on HRCT in patients with diffuse lung disease and their significance and differential diagnosis, diagnostic algorithms, an illustrated glossary of HRCT terms, and a Quick Reference Guide at the beginning of the book, which illustrates the common appearances of the most common diffuse lung diseases encountered in clinical practice. This guide may be of value in the initial differential diagnosis of clinical cases and is also intended to serve as an illustrated index to the detailed descriptions of diseases found elsewhere in the book.

W.R.W.
N.L.M.
D.P.N.

Preface to the First Edition

In his paper "A New Look at Pattern Recognition of Diffuse Pulmonary Disease," Ben Felson (1) reviewed the many problems that are inherent in any attempt to precisely characterize diffuse lung disease on the basis of plain radiographic findings. Although he was a great proponent of pattern recognition and an accomplished master of this technique, he stated in the first sentence of this paper that "the common practice of describing the histologic distribution of pulmonary lesions from their radiographic patterns is often inaccurate." He continued:

After many years of trying and testing, I have convinced myself that certain patterns of diffuse pulmonary shadows can be distinguished in most patients. Nevertheless I have had considerable difficulty in teaching others how to do it. In fact, a number of respected colleagues who also claim success in pattern recognition often differ with me when viewing the same films. Others even feel that the pattern approach to chest radiography is so unreliable it should be abandoned altogether.

Why the problems?

As indicated by Dr. Felson, and as we review in the introduction to this book, chest radiographs are limited in their ability to characterize lung morphology precisely and to represent the pathological alterations in morphology that occur in the presence of lung disease. High-resolution CT (HRCT), however, provides both the radiologist and the clinician with a tool capable of accurately demonstrating gross lung anatomy and accurately characterizing abnormal findings. The correlation between HRCT findings and pathological findings is excellent and certainly exceeds that possible with plain radiographs. As discussed by Roberta Miller in the Foreword to this book, to the extent that gross pathology can be used to diagnose lung disease, HRCT can

as well. In the past 5 years, HRCT has revolutionized the radiologic approach to diagnosing lung disease.

A further advantage of HRCT is that the interpretation of HRCT scans is easier to teach than is the interpretation of chest radiographs. Because of the clarity and precision with which HRCT represents lung anatomy, there is much less individual variation in interpreting HRCT than there is with chest radiographs. It is much easier to recognize HRCT findings as something one has seen before (e.g., a thick-walled bronchus always looks like a thick-walled bronchus), and to understand what they represent. Far fewer HRCT cases must be classified as belonging to the "I don't know" pattern (1) than is necessary when interpreting plain films.

In this book, we limit our discussion of HRCT findings, both normal and abnormal, and the HRCT descriptions of diseases to what is known and described. We avoid speculating as to what the HRCT might look like in patients with one disease or another based on the plain film findings. As indicated previously, the notable inaccuracy of plain films would make this a hazardous endeavor.

In answering his own question, "Why the problems?" with plain radiographs, Dr. Felson replied, "I believe inconsistent terminology and certain misconceptions in respect to pathologic alterations are responsible for many of the difficulties" (1). This is a problem we hope to avoid. In this book, we define and name HRCT findings, whenever possible, in relation to specific anatomical structures.

REFERENCE

1. Felson B. A new look at pattern recognition of diffuse pulmonary disease. *AJR Am J Roentgenol* 1979;133:183-189.

Acknowledgments

We want to very gratefully acknowledge Martha L. Warnock, MD, Professor Emerita of Pathology at the University of California, San Francisco, for her numerous contributions of anatomical and pathological specimens shown in this book, for her ongoing support over the years, and for her repeated, but largely futile efforts to teach one of us about the pathology of lung disease.

We would also like to extend our deep appreciation to Martha Helmers and Tony Jalandoni, photographers

extraordinaire, who have been a constant source of support despite countless impositions on their time and patience.

We also thank Drew Toigian, MD, University of Pennsylvania Medical Center for his timely insights into the state of the art of quantitative CT imaging, and our numerous other colleagues who have graciously provided us with illustrations.

Quick Reference Guide

QUICK REFERENCE TO HIGH-RESOLUTION COMPUTED TOMOGRAPHY DIAGNOSIS OF DIFFUSE LUNG DISEASE

In the following pages, in alphabetical order, we provide examples of the most common appearances of the most common lung diseases encountered in reading high-resolution CT. It is our hope that this will serve as a quick reference and an illustrated index to the detailed descriptions of findings found elsewhere in this book, and as a diagnostic aid when a reader is faced with an unfamiliar HRCT appearance.

ACUTE INTERSTITIAL PNEUMONIA (AIP)

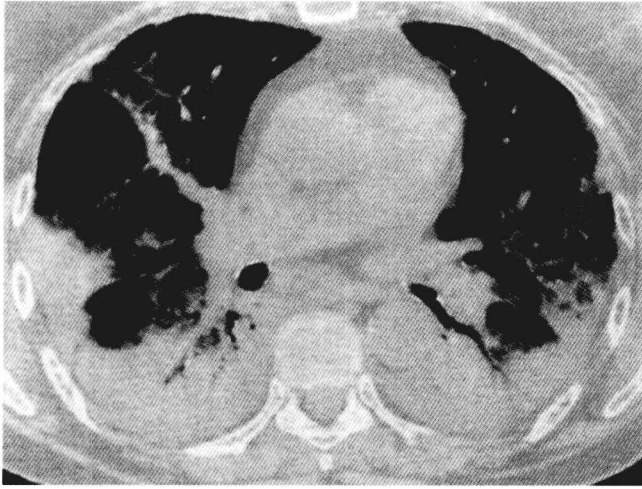
(See pages 206–209.)

HRCT Findings

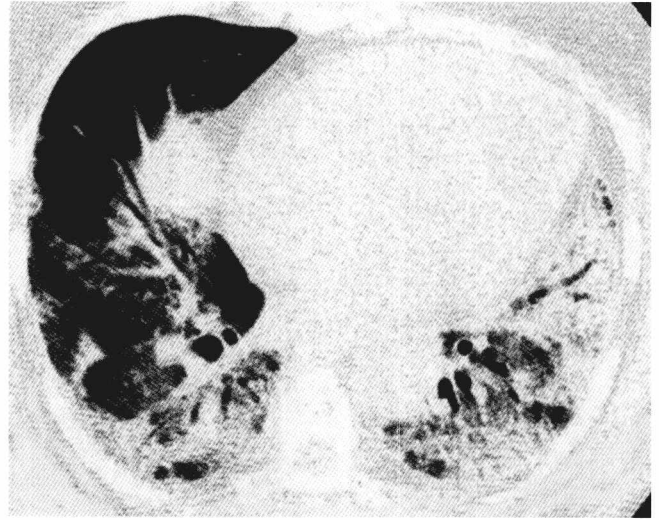
Extensive bilateral ground-glass opacities and airspace consolidation

Architectural distortion

Abnormalities predominantly basilar and dependent



Bilateral consolidation involving posterior lung bases.



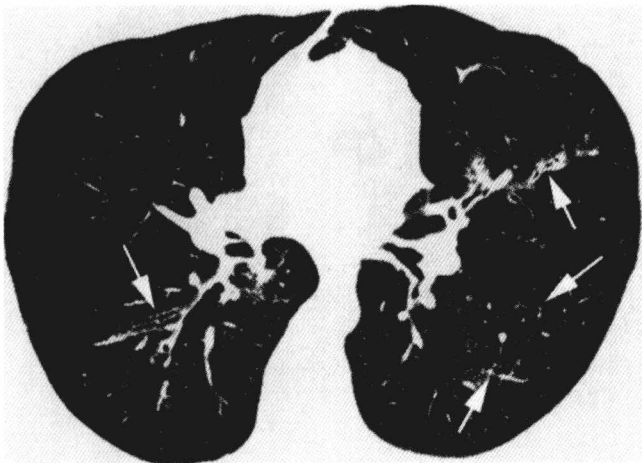
Bilateral lower lobe consolidation and ground-glass opacity.

ALLERGIC BRONCHOPULMONARY ASPERGILLOSIS

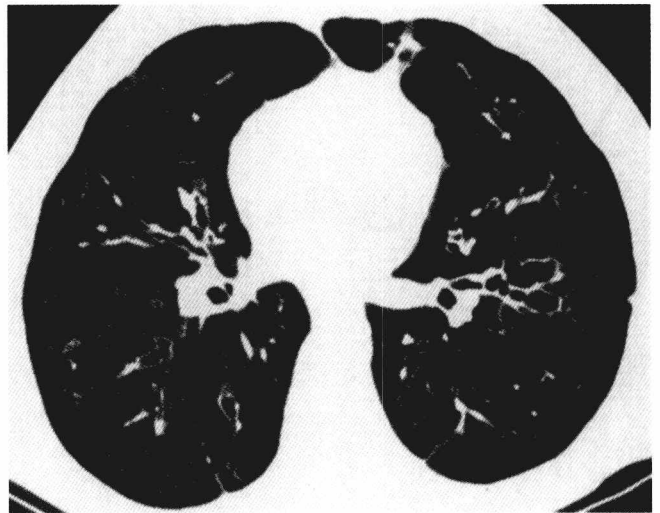
(See pages 521–525.)

HRCT Findings

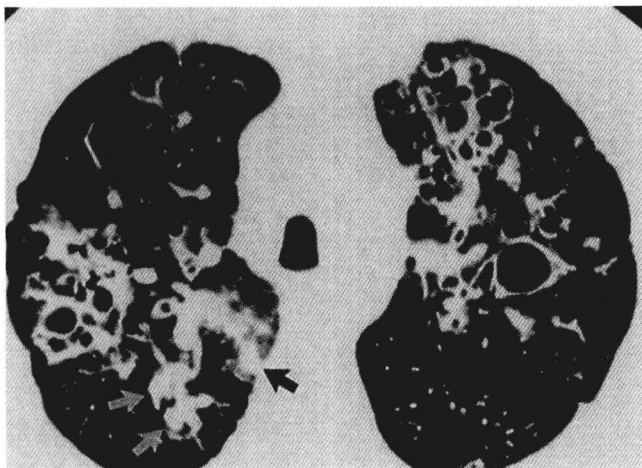
Central bronchiectasis
Mucous plugging
High-attenuation mucous plugs
Tree-in-bud
Atelectasis
Mosaic perfusion
Air-trapping on expiratory scans



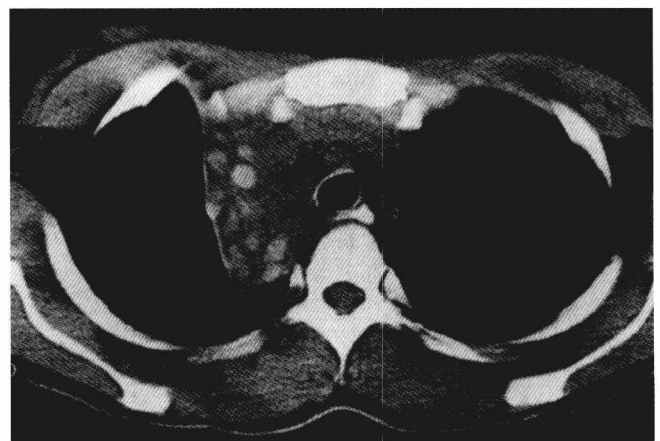
Early disease with mild central bronchiectasis (*arrows*).



Central bronchiectasis.



Late disease with bronchiectasis and mucous plugging (*arrows*).



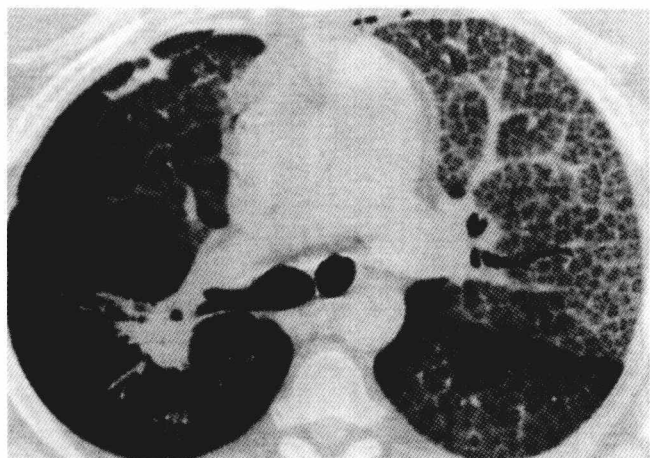
High density mucous plugs with atelectasis.

ALVEOLAR PROTEINOSIS

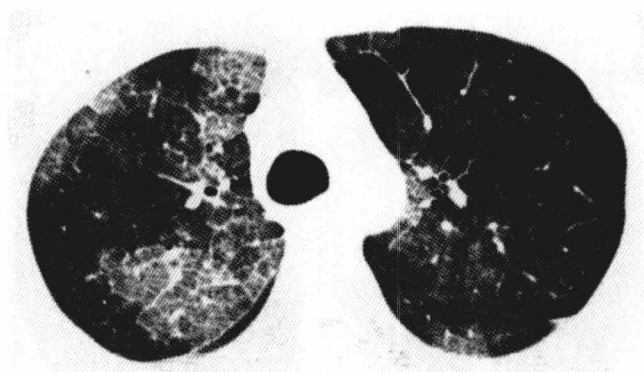
(See pages 479–482.)

HRCT Findings

- Patchy ground-glass opacity
- Smooth septal thickening in abnormal areas
- Crazy-paving
- Consolidation
- Patchy or geographic distribution



Geographic ground-glass opacity with septal thickening (crazy-paving).



Crazy-paving with a patchy distribution.



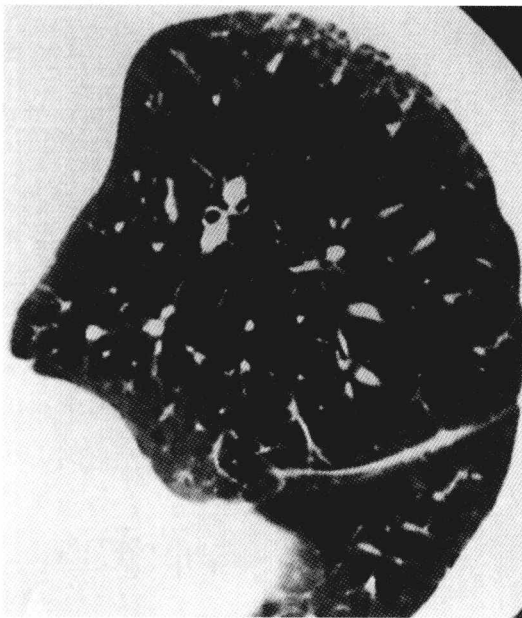
Crazy-paving with a patchy distribution.

ASBESTOSIS AND ASBESTOS-RELATED DISEASE

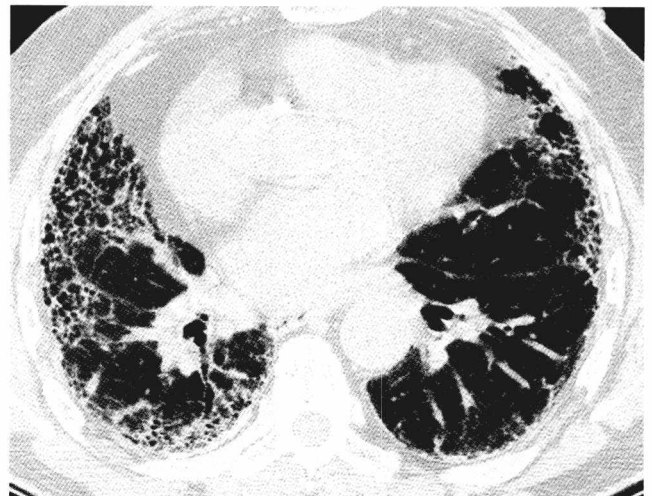
(See pages 302–311.)

HRCT Findings

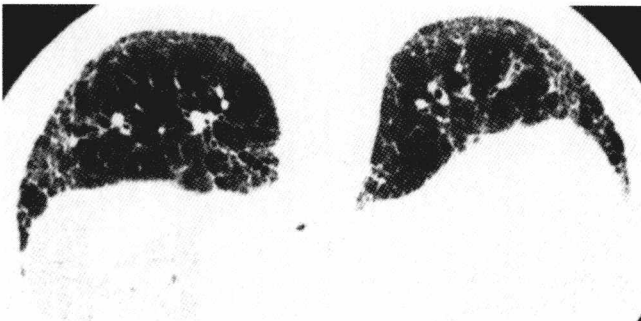
- Pleural thickening and plaques
- Subpleural dotlike opacities in early disease
- Findings of fibrosis
- Honeycombing in advanced disease
- Subpleural lines
- Parenchymal bands in association with pleural thickening
- Earliest abnormalities posterior and basal



Small subpleural nodules in early asbestosis.



Honeycombing and pleural thickening in asbestosis.



Subpleural intralobular interstitial thickening in asbestosis.



Parenchymal bands associated with pleural disease.

BRONCHIOLITIS OBLITERANS (CONSTRUCTIVE BRONCHIOLITIS)

(See pages 541–543.)

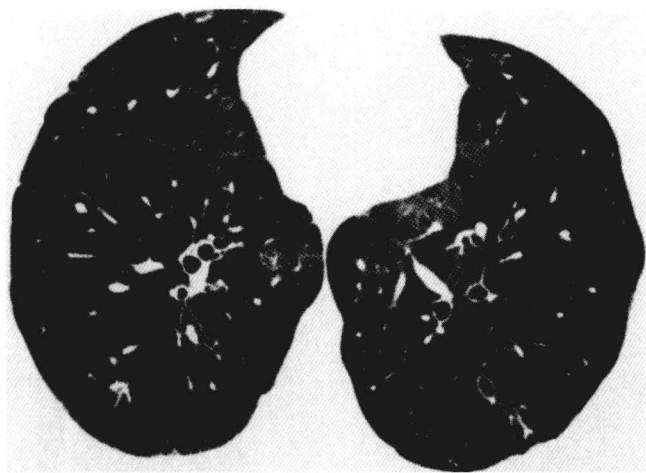
HRCT Findings

Bronchiectasis

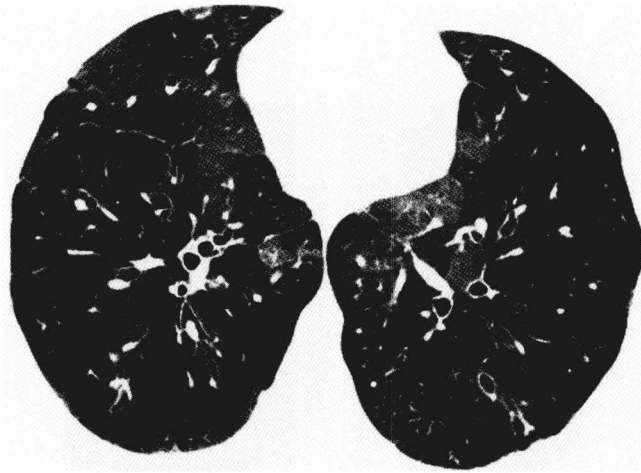
Mosaic perfusion, usually patchy

Air-trapping on expiration, usually patchy

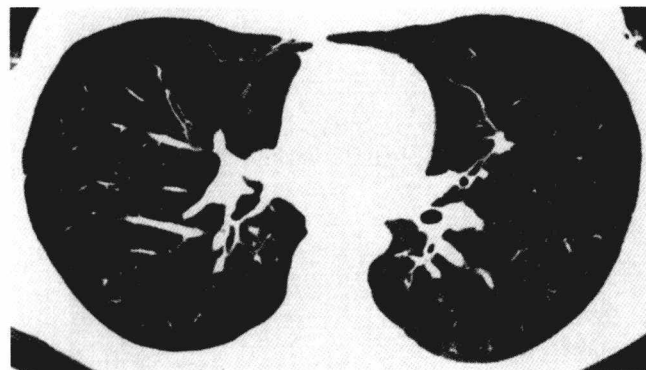
Air-trapping on expiration despite normal inspiratory scans



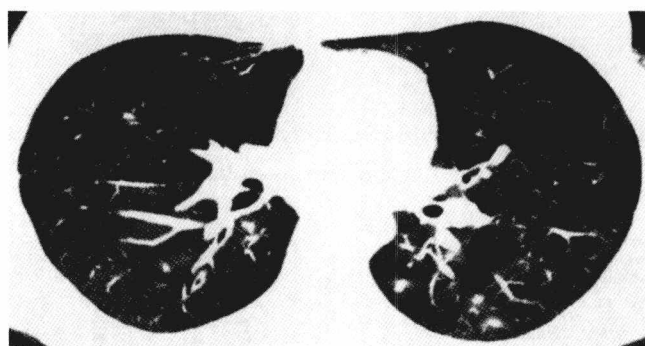
Late disease: extensive bronchiectasis and mosaic perfusion.



Late disease: extensive bronchiectasis and mosaic perfusion.



Mild bronchiectasis and mosaic perfusion.



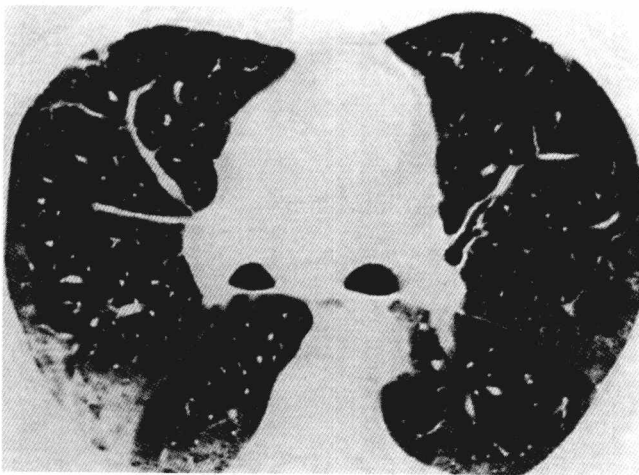
Air-trapping on expiratory scan.

BRONCHIOLITIS OBLITERANS ORGANIZING PNEUMONIA (BOOP), ORGANIZING PNEUMONIA (OP), CRYPTOGENIC ORGANIZING PNEUMONIA (COP)

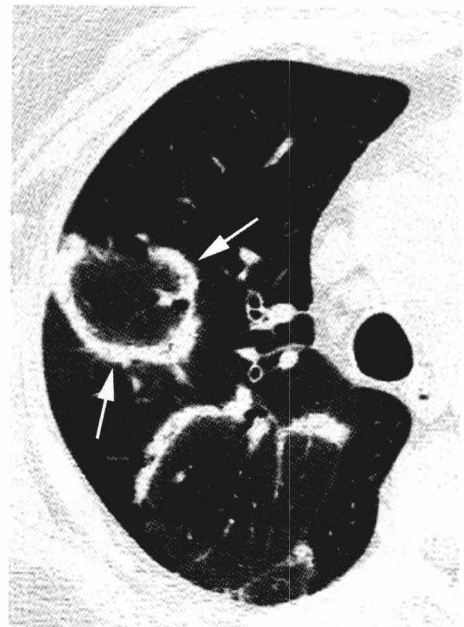
(See pages 199–206.)

HRCT Findings

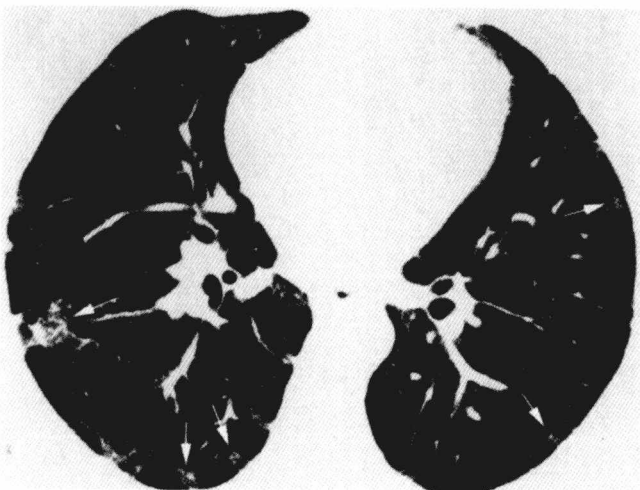
Patchy bilateral airspace consolidation
Ground-glass opacity
Subpleural or peribronchovascular distribution, or both
Bronchial wall thickening or dilatation
Centrilobular nodules
Large nodules
Atoll or reversed-halo sign



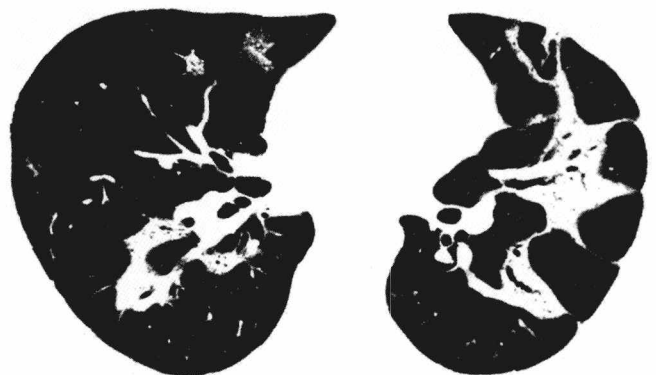
Patchy subpleural ground-glass opacity.



Opacities with the atoll or reversed halo sign (arrows).



Ill-defined centrilobular nodules (*arrows*).



Patchy peribronchial consolidation.

CHRONIC EOSINOPHILIC PNEUMONIA

(See pages 347–349.)

HRCT Findings

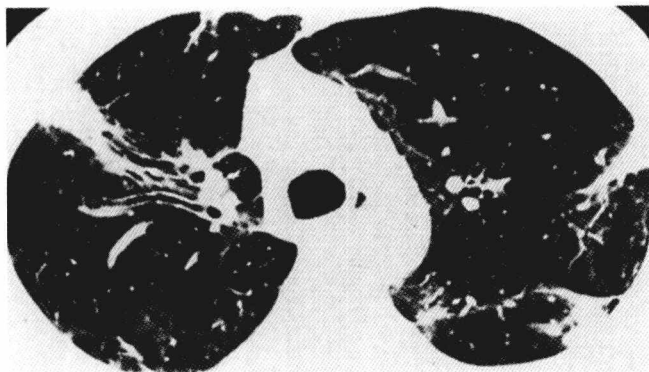
Patchy unilateral or bilateral airspace consolidation

Peripheral, middle, and upper-lung predominance

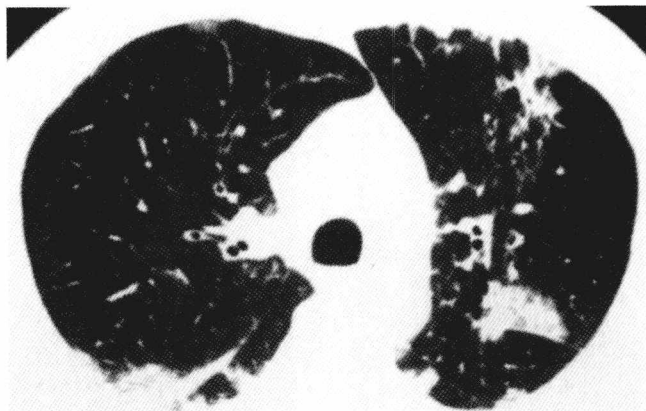
Ground-glass opacity

Subpleural lines

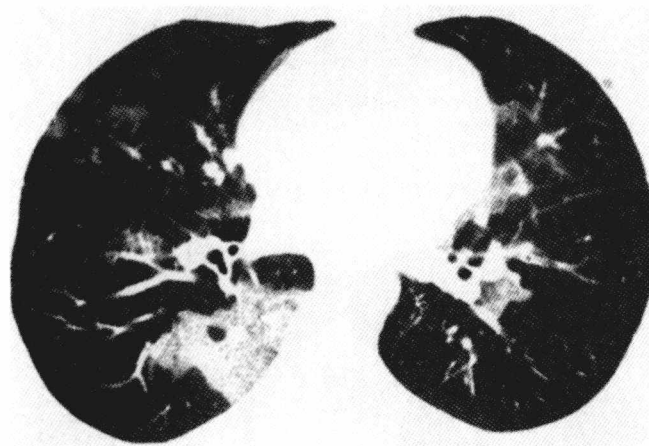
Appearance similar to BOOP



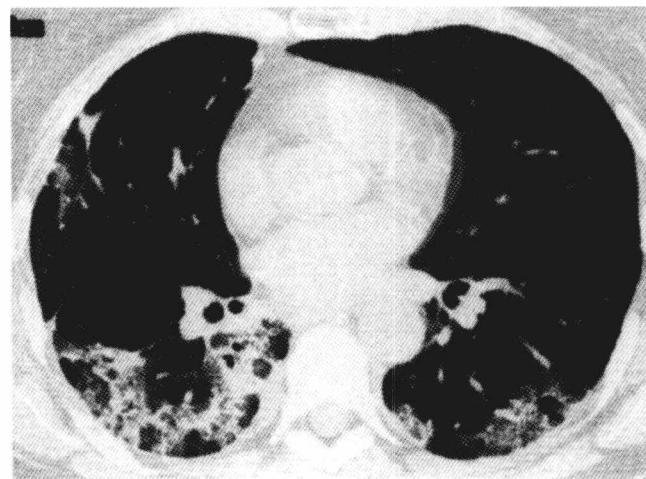
Patchy subpleural consolidation and linear opacities.



Patchy subpleural consolidation.



Patchy subpleural ground-glass opacity.



Patchy subpleural ground-glass opacities, consolidation, and linear opacities.

CYSTIC FIBROSIS

(See pages 514–519.)

HRCT Findings

Bronchiectasis, central bronchi and upper lobes involved in all cases

Bronchial wall thickening, right upper lobe first involved

Mucous plugging

Tree-in-bud

Large lung volumes

Areas of atelectasis

Mosaic perfusion

Air-trapping on expiration



Early disease: bronchial wall thickening (*open arrow*), mucoid impaction (*white arrow*), and tree-in-bud (*small arrows*).



Late disease: central bronchiectasis and mosaic perfusion.



Late disease: bronchiectasis and air trapping on an expiratory scan.

CYTOMEGALOVIRUS PNEUMONIA

(See page 443–446.)

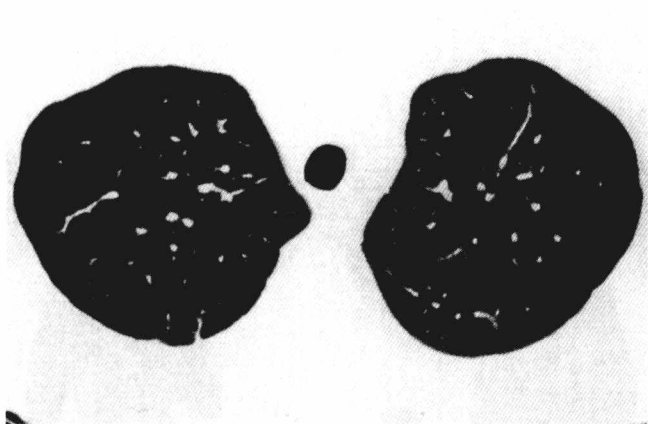
HRCT Findings

Patchy bilateral ground-glass opacity, consolidation, or both

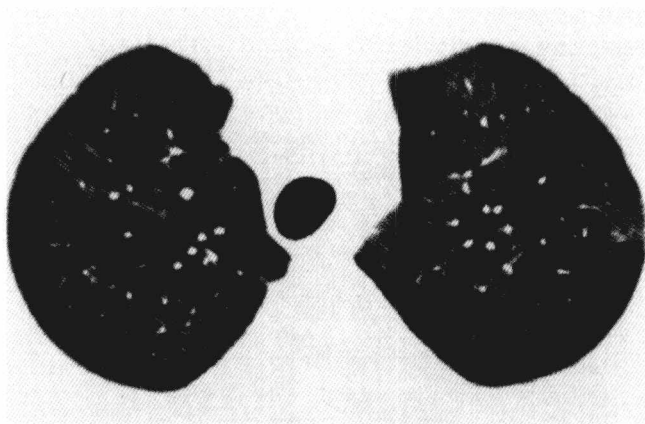
Reticulation (resolving disease)

Crazy-paving

Centrilobular nodules



Patchy ground-glass opacity.



Patchy ground-glass opacity.



Crazy-paving: patchy ground-glass opacity with septal thickening (*arrow*).

DESQUAMATIVE INTERSTITIAL PNEUMONIA (DIP)

(See pages 212–215.)

HRCT Findings

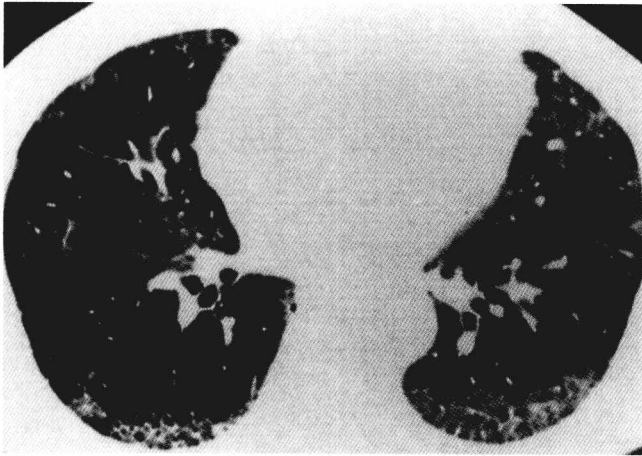
Bilateral, patchy ground-glass opacity

Subpleural and basal predominance

Minimal findings of fibrosis (reticulation)

Small cysts in abnormal areas

Air trapping in some patients on expiration



Subpleural ground-glass opacity with mild reticulation.



Subpleural ground-glass opacity.