SYNOPSIS OF CLINICAL PULMONARY DISEASE

Edited by
ROGER S. MITCHELL
THOMAS L. PETTY

THIRD EDITION

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ROGER S. MITCHELL, M.D.

Professor of Medicine Emeritus; formerly Director,
Webb-Waring Lung Institute; Head, Division of Pulmonary Sciences; and
Chief of Staff, Veterans Administration Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

THOMAS L. PETTY, M.D.

Professor of Medicine and Anesthesia and
Head, Division of Pulmonary Sciences,
University of Colorado Health Sciences Center,
Denver, Colorado

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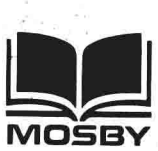

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CONTRIBUTORS

DARRYL D. BINDSCHADLER, M.D.

Associate Clinical Professor of Medicine,
University of Colorado Health Sciences Center,
Denver, Colorado; now of Cheyenne, Wyoming

REUBEN M. CHERNIACK, M.D.

Chairman, Department of Medicine,
National Jewish Hospital; Professor and
Vice-Chairman, Department of Medicine,
University of Colorado Health Sciences Center,
Denver, Colorado

PAUL T. DAVIDSON, M.D.

Assistant Professor of Medicine,
National Jewish Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

ROBERT B. DREISIN, M.D.

Assistant Professor of Medicine,
National Jewish Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

JAMES H. ELLIS, Jr., M.D.

Associate Clinical Professor of Medicine and
Chief, Pulmonary Department,
Rose Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

ENRIQUE FERNANDEZ, M.D.

Assistant Professor of Medicine,
National Jewish Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

JAMES T. GOOD, Jr., M.D.

Assistant Professor of Medicine,
Denver General Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

FREDERICK N. HANSON, M.D.

Senior Fellow in Pulmonary Medicine,
Cardiovascular-Pulmonary Research
Laboratory, University of
Colorado Health Sciences Center,
Denver, Colorado

RUTH N. HARADA, M.D.

Assistant Professor of Medicine,
Webb-Waring Lung Institute,
University of Colorado Health Sciences Center,
Denver, Colorado

DAVID W. HUDGEL, M.D.

Assistant Professor of Medicine,
National Jewish Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

THOMAS M. HYERS, M.D.

Assistant Professor of Medicine,
Veterans Administration Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

MICHAEL D. ISEMAN, M.D.

Associate Professor of Medicine and
Associate Director, Pulmonary Medicine
Service, Denver General Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

TALMADGE E. KING, Jr., M.D.

Assistant Professor of Medicine,
Veterans Administration Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

ROGER S. MITCHELL, M.D.

Professor of Medicine Emeritus; formerly
Director, Webb-Waring Lung Institute;
Head, Division of Pulmonary Sciences; and
Chief of Staff, Veterans Administration
Medical Center, University of Colorado
Health Sciences Center,
Denver, Colorado

THOMAS A. NEFF, M.D.

Associate Professor of Medicine and Chief,
Pulmonary Service, Denver General Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

THOMAS L. PETTY, M.D.

Professor of Medicine and Anesthesia and
Head, Division of Pulmonary Sciences,
University of Colorado Health Sciences Center,
Denver, Colorado

JOHN E. REPINE, M.D.

Associate Professor of Medicine and Assistant
Director, Webb-Waring Lung Institute,
University of Colorado Health Sciences Center,
Denver, Colorado

LAWRENCE H. REPSHER, M.D.

Associate Clinical Professor of Medicine,
Lutheran Medical Center, University of
Colorado Health Sciences Center,
Denver, Colorado

STEVEN A. SAHN, M.D.

Associate Professor of Medicine,
University Hospital, University of
Colorado Health Sciences Center,
Denver, Colorado

JOHN A. SBARBARO, M.D.

Associate Professor of Medicine and Deputy
Director, Department of Health and Hospitals,
University of Colorado Health Sciences Center
Denver, Colorado

MARVIN I. SCHWARZ, M.D.

Associate Professor of Medicine and
Chief, Pulmonary Medicine,
Veterans Administration Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

CHARLES SCOGGIN, M.D.

Associate Professor of Medicine,
University Hospital, University of
Colorado Health Sciences Center,
Denver, Colorado

MICHAEL SHASBY, M.D.

Assistant Professor of Medicine,
University of Virginia School of Medicine,
Charlottesville, Virginia

RICHARD H. SIMON, M.D.

Senior Fellow in Pulmonary Medicine,
University Hospital, University of
Colorado Health Sciences Center,
Denver, Colorado

CHARLES W. VAN WAY III, M.D.

Associate Professor of Surgery and Chief,
Surgical Service, Denver General Hospital,
University of Colorado Health Sciences Center,
Denver, Colorado

H. DENNIS WAITE, M.D.

Assistant Clinical Professor of Medicine,
Rose Medical Center,
University of Colorado Health Sciences Center,
Denver, Colorado

FOREWORD

Pulmonary medicine has come a long way in the past 20 years. It seems incredible that 23 years ago as a senior medical student I chose an elective in pulmonary medicine with Dr. Mitchell. Very clearly, as I look back, this was the major force that kindled my interest in the fascinating field of pulmonary medicine. Since that time many medical students have sought elective training in pulmonary medicine at the University of Colorado Health Sciences Center. Currently over 50% of our graduating class and many students from other medical schools choose our elective in the senior year. Hopefully they all become "turned on" to the delights of the practice and science of pulmonary disease.

Thus, members of the Division of Pulmonary Sciences have been particularly dedicated to the task of revising chapters from the first two editions of this synopsis, or writing new chapters, with the hope that collectively we may be able to spark the imagination of many more undergraduate physicians, house officers, and colleagues in the allied health professions who will be tomorrow's servants for patients with diseases of the respiratory system.

I personally thank my former chief for his continued efforts in medical education in our field, particularly for the effort of this synopsis and all it means.

Thomas L. Petty

PREFACE

The first edition of this introduction to the intricacies of chest medicine, published in 1974, was sufficiently successful to prompt a second edition. This third edition is the result of a request from the publisher. In response to suggestions, the present volume goes into more detail, adds many illustrations, including both chest films and tabular material, and updates and expands the bibliographies.

As before, the intended audience for this book includes both undergraduate and postgraduate medical students and practitioners other than the pulmonary specialist.

All of the contributors have been members of the faculty of the University of Colorado Health Sciences Center, and all but one, a surgeon, are members of the Division of Pulmonary Sciences, Department of Medicine, to which all proceeds derived from the sale of this volume will again be donated.

I am very pleased to have my friend and colleague, Thomas L. Petty, join me in editing this third edition.

Roger S. Mitchell

SYNOPSIS OF
CLINICAL PULMONARY DISEASE

CONTENTS

Chapter 1

LUNG STRUCTURE AS RELATED TO FUNCTION

Ruth N. Harada *and* **John E. Repine**

Human beings can live for weeks without food and days without water, but they cannot survive for more than a few minutes without oxygen. A continuous external supply of oxygen is essential for survival because no significant amount of oxygen is stored in the body.

RESPIRATORY SYSTEM FUNCTION

The major function of the respiratory system—the lungs—is to procure oxygen from the external environment and to eliminate carbon dioxide at rates required by tissue metabolism. The overall success of the lungs depends on a patent airway system, intact pulmonary parenchyma (including the vascular bed), adequate cardiac output, normal neuromuscular function, and intact central nervous system (CNS) ventilatory control. Other less obvious but equally important respiratory tract functions include the ability to generate airflow for speech, to act as a mechanical and immunologic sieve for noxious gases or inert and infectious particles in the environment, to degrade drugs and endogenous chemical substances, and to synthesize and secrete numerous proteins and lipids.

RESPIRATORY SYSTEM STRUCTURE

The respiratory tract consists of two basic parts: the *conducting airways* and the *respiratory unit* (Fig. 1-1). The conducting airways are passageways through which inspired air from the external environment reaches the alveoli; conversely, expired air from the alveoli is removed to the atmosphere. The upper airways consist of the nose, pharynx, and larynx; they warm and humidify air as well as remove aerosol particles. The *tracheobronchial tree*

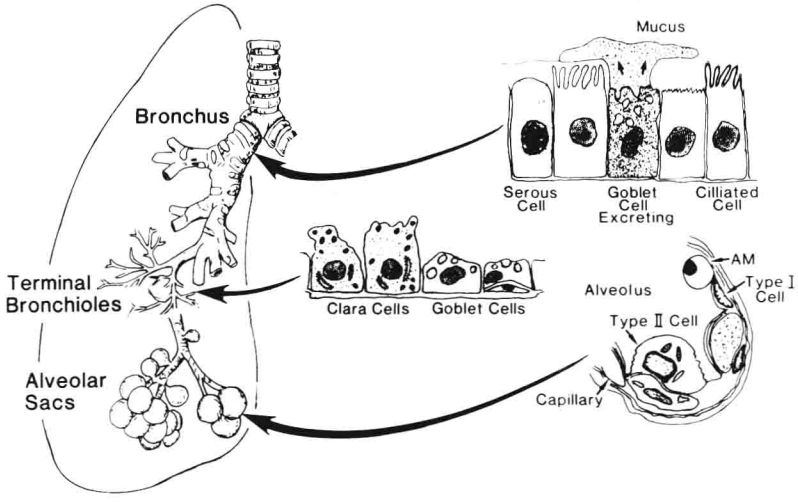

FIG. 1-1. Schematic gross and microscopic lung anatomy.

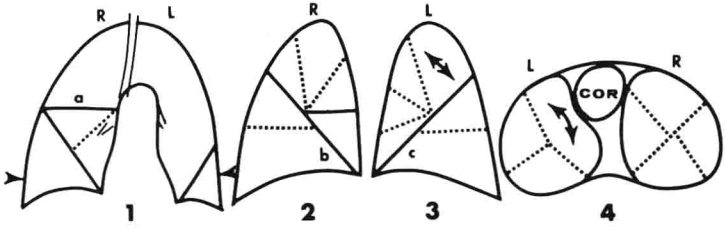

FIG. 1-2. Schematic lung segmental anatomy.

branches irregularly and provides increasing surface area at each branching. The 16 segmental bronchi arising at the tracheobronchial tree's third branching are conduits for anatomic segments of the lungs (Fig. 1-2). The walls of the airways—that is, the *trachea* and the *bronchi*—contain incomplete, cartilaginous, support rings that are lined with pseudostratified, ciliated, columnar epithelium interspersed with *goblet cells* and *mucous glands.*

The respiratory unit consists of the terminal bronchiole, respiratory bronchiole, alveolar ducts, and the alveoli. The alveolar ducts and alveoli are the functional area of gas exchange. The bronchiolar walls consist mainly of a few ciliated cells and many nonciliated cells called Clara cells. The alveoli are composed of two types of epithelial cells. Type I pneumocytes are simple squamous cells that form a thin layer over most of the alveolar wall and seem anatomically specialized to provide a slender barrier for gaseous diffusion.

Type II cells (granular pneumocytes) are metabolically active and elaborate surfactant, a lipoprotein that lines and stabilizes the inherently unstable alveolar surface. In addition, alveolar macrophages are normally found adherent to alveolar walls and are a major defense against inhaled particles and microorganisms.

MECHANICS OF RESPIRATION

Gas transfer between the external atmosphere and the internal gas phase of lung alveoli is accomplished through a "bellows" mechanism (i.e., the alternate expansion and contraction of a hollow chamber in communication with the atmosphere). In humans the *thoracic cage* is a hollow chamber able to expand in volume by contraction of the intercostal muscles, the diaphragm, and, to a lesser extent, the scalene and abdominal muscles. During expansion of the thoracic cage, intrapleural pressures become subatmospheric, causing air to enter the lung. In contrast, during expiration the intrapleural pressure becomes greater than the atmospheric pressure, and air leaves the lung. Expiration results from the intrinsic elastic recoil of the lung and the contraction and relaxation of various respiratory muscles. After fresh air enters the alveoli it is brought into contact with a thin membrane consisting of alveolar and capillary endothelial cells. At this location, a passive diffusion of oxygen and carbon dioxide takes place.

Factors that determine the rate of gas diffusion through the pulmonary membrane are as follows: (1) the greater the pressure difference across the membrane, the greater the rate of gas exchange, (2) the greater the area of pulmonary membrane (normal adults have an estimated 90 m^2 effective gas exchange surface), the greater the amount of diffusion, and (3) the thinner the pulmonary membrane, the greater the diffusion rate. Finally, note that the diffusion coefficient of a gas determines the amount of a given gas that dissolves in the membrane. This is important, since carbon dioxide is approximately 20 times more soluble than oxygen.

CONTROL OF BREATHING

The respiratory control system regulates a complex series of activities. It must maintain a rhythmic breathing pattern as well as adjust minute ventilation through changes in tidal volume and respiratory rate to meet the demands for gas exchange in the lung. This system must also adjust the breathing pattern during speech, change in posture, swallowing, and other activities.

Anatomically the respiratory centers have not been precisely defined, but

they are believed to consist of neurons scattered throughout the cerebral cortex, pons, and medulla. Cerebral control is probably responsible for voluntary acts of breathing such as hyperventilation and breath holding. The involuntary breathing centers consist of neurons in the pons and medulla. The medullary oscillatory pattern is modulated by neural inputs from the cortex and pons and from peripheral and central chemoreceptors. Peripheral chemoreceptors are located at the bifurcation of the common carotid artery (carotid body), in proximity to the aortic arch (aortic body), and centrally in proximity to the medulla. Stimulation of these receptors increases the rate and depth of breathing. The most potent stimulus to chemoreceptors is hypoxemia (Pao_2 less than 60 mm Hg). Hypercarbia, acidosis, decreased cardiac output, and hyperthermia also stimulate the chemoreceptors and thereby increase ventilation.

VENTILATION-PERFUSION RELATIONSHIPS

The job of pulmonary gas exchange is to bring air and blood into juxtaposition on either side of a thin diffusion membrane so that oxygen and carbon dioxide transfer can occur. Even in healthy people, however, neither all the "fresh" inspired air nor all the "stale" systemic venous blood reaches the effective exchange membrane. In disease states this inefficiency of ventilation, perfusion, or both may be greatly magnified.

The relationship of alveolar ventilation ($\dot{V}_A$) to pulmonary capillary blood flow ($\dot{Q}c$) is called the ventilation-perfusion ratio (V/Q). Each gas exchange unit has its own V/Q ratio, and the sum of these ratios is the overall V/Q ratio of the lungs. V/Q abnormalities can arise as follows:

1. Inspired air can remain in the conducting airways; indeed, some of it normally does. This anatomic dead space consists of trachea, bronchi, and bronchioles and is approximately 150 cc, or one third of every tidal breath.
2. Inspired air can reach nonperfused alveoli.
3. Systemic venous blood can pass through anatomic channels that bypass alveoli.
4. Systemic venous blood can reach nonventilated alveoli.

Conditions 1 and 2 are *anatomic* and *physiologic dead space,* or *wasted,* ventilation. Conditions 3 and 4 are *anatomic* and *physiologic shunts.* Wasted ventilation implies adequate ventilation with decreased or absent perfusion; a shunt implies adequate blood flow with absent or decreased ventilation. A V/Q disturbance is the most common cause of hypoxemia in the absence of hypoxia or circulatory impairment.

PULMONARY VASCULATURE

The pulmonary circulation is unlike the systemic circulation because (1) the entire cardiac output passes through the lungs and (2) pulmonary circulation replenishes blood with oxygen rather than delivering oxygen to tissues. Another unique characteristic of the pulmonary circulation is the expansile nature of the pulmonary vasculature; venous pressure and vascular resistance are only one tenth that of the systemic circulation. A fivefold increase in pulmonary blood flow is associated with only a minimal increase in pulmonary arterial pressure. In experimental animal models 75% of the pulmonary vascular bed must be occluded before pulmonary hypertension develops. The presence of pulmonary hypertension therefore implies the existence of widespread vascular disease.

Hypoxia and acidosis can cause generalized or localized pulmonary arteriolar constriction. Poorly aerated areas of the lung develop hypoxemia and acidosis, which in turn lead to pulmonary vasoconstriction and decreased blood flow.

LUNG ACTIVITIES

Metabolic functions

Although the metabolic activities that occur in the lung are not unique, the lung is unique in that it filters the body's entire blood volume before blood enters the systemic circulation. It has recently been established that the lung has an important pharmacokinetic function: the cells and enzyme systems of the pulmonary vascular bed change the biologic activity of a variety of substances presented to them. Thus the pulmonary circulation is well suited to monitor and control levels of circulating hormones and biologically active substances and, consequently, to modify their effects on the arterial circulation. Just as the respiratory function adds oxygen and removes carbon dioxide from the lung, so the metabolic function adds angiotensin II, histamine, and prostaglandins and removes 5-hydroxytryptamine, bradykinin, and noradrenaline from the systemic circulation. Thus the lung has pharmacokinetic functions of uptake, storage, and enzymatic degradation as well as "endocrine" functions. Various stimuli have been shown to release vasoactive substances from the lung, including histamine, serotonin, vasoactive prostaglandins, and still-unidentified vasoactive lung peptides.

Immune functions

The respiratory tract exposes a total surface area of approximately 90 m^2 to approximately 10,000 L of ambient air every day. Ambient inspired air not

only contains the oxygen vital to survival; it contains noxious gases and a multitude of particulates that the lungs must exclude to maintain good health.

The upper respiratory tract removes most noxious gases and particles, including potential pathogens. Small inhaled particles less than 5 μm may be deposited distal to ciliated epithelial portions of the tracheobronchial tree and enter the alveolar spaces. The mechanism of removal of many noxious gases and particulates in the upper respiratory tract is the *mucociliary escalator.* Most of the noxious gases and large particles are absorbed in the mucous lining of the upper airways and tracheobronchial tree; they are eventually coughed up or swallowed through rhythmic and unidirectional beating of the cilia.

When a particle or gas enters the alveolar spaces, a different clearance apparatus takes over. In the alveolus, the resident phagocytic cell—the alveolar macrophage—and immunoglobulins and enzymes inactivate and remove particles by way of the mucociliary escalator or through lymphatic channels. When local defenses fail, chemical mediators from the inflamed part of the lung can recruit polymorphonuclear leukocytes and other cellular and humoral factors from the blood. Interestingly, recent evidence indicates that many of these mechanisms that usually protect the lung against infection may, under such circumstances as cigarette smoking, environmental exposure, or allergy, mediate lung damage.

• • •

In summary, the lung mediates not only gas exchange, but also regulates numerous immunologic and biochemical functions. Abnormalities in the lung's various structures and/or functions and how they contribute to various lung disorders will be described in subsequent chapters.

LUNG SEGMENTAL ANATOMY (Fig. 1-2)

In view 1 the horizontal fissure *(a)* separates the right upper lobe from the right middle lobe, the dotted line separates the two segments of the right middle lobe (medial and lateral), and the two diagonal lines near the base mark the lateral and inferior margins of the right middle lobe and the left upper lobe, respectively.

In view 2, a lateral view of the right lung, the long (diagonal) fissure *(b)* separates the right lower lobe from the right upper and middle lobes. The dotted lines in the right upper lobe demarcate its three segments (anterior, apical, and posterior); the dotted line in the right lower lobe identifies the superior segment of the right lower lobe.

In view 3, a lateral view of the left lung, the long (diagonal) fissure *(c)* separates the left upper lobe from the left lower lobe; the dotted lines show the left upper lobe segments (apical posterior [the fusion indicated by the double arrow], anterior, superior lingular, and inferior lingular); and the superior segment of the left lower lobe is again identified.

In view 4, a horizontal section at the level noted by the two markers in view 1, the basal segments of both lower lobes are identified—on the right are the medial, lateral, anterior, and posterior basal, and on the left the anteromedial basal fusion is again identified by a double arrow.

Segmental anomalies are not uncommon.

Atelectasis of the right middle lobe may be seen on the lateral projection as an angulated linear shadow; atelectasis of the upper and lower lobes may be seen on the posteroanterior projection as linear shadows, except when held laterally by dense pleural adhesions.

SUGGESTED READINGS

Bakhle, Y.S., and Vane, J.R., editors: Metabolic functions of the lung, New York City, 1977, Marcel Dekker, Inc.

Bates, D.V., Macklem, P.T., and Christie, R.V.: Respiratory function in disease: an introduction to the integrated study of the lung, ed. 2, Philadelphia, 1971, W.B. Saunders Co.

Bouhuys, A.: Breathing: physiology, environment and lung disease, New York City, 1974, Grune & Stratton, Inc.

Brain, J.D., Proctor, D.I., and Reid, L.M., editors: Respiratory defense mechanisms, New York City, 1977, Marcel Dekker, Inc.

Crystal, R.G., editor: The biochemical basis of pulmonary function, New York City, 1976, Marcel Dekker, Inc.

Davies, D.G., and Barnes, C.D., editors: Regulation of ventilation and gas exchange, New York City, 1978, Academic Press, Inc.

Fishman, A.P.: Pulmonary disease and disorders, New York City, 1980, McGraw-Hill Book Co.

Grodins, F.S., and Yamashiro, S.M.: Respiratory function of the lung and its control, New York City, 1978, Macmillan Publishing Co., Inc.

Junod, A.F., and deHaller, R., editors: Lung metabolism, New York City, 1975, Academic Press, Inc.

Kirkpatrick, C.H., and Reynolds, H.F., editors: Immunologic and infectious reactions in the lung, New York City, 1976, Marcel Dekker, Inc.

Murray, J.F.: The normal lung, Philadelphia, 1976, W.B. Saunders Co.