Respiratory Medicine

Series Editors: Sharon I.S. Rounds · Anne Dixon · Lynn M. Schnapp

David A. Kaminsky · Charles G. Irvin
Editors

Pulmonary Function Testing

Principles and Practice

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Preface

Welcome to *Pulmonary Function Testing: Principles and Practice*. You might ask why do we need another book on pulmonary function tests (PFTs)? We have been involved in teaching PFTs to students, residents, and fellows for many years and have realized that there appear to be two main types of educational resources available. On the one hand, there are many classic books about pulmonary physiology, such as West's *Respiratory Physiology: The Essentials* and the American Physiological Society's *Handbook of Physiology*. And there are also many excellent references about how to perform and interpret pulmonary function tests, such as Ruppel's *Manual of Pulmonary Function Testing* and Wanger's *Pulmonary Function Testing: A Practical Approach*. What we felt was needed was a resource that combined the best of both worlds, including not only details about how each PFT is performed and interpreted but also the physiological basis of each test. In addition, this level of content would best be geared toward the postgraduate trainee or fellow in pulmonary medicine and should include a section on the practical "how to" run a PFT lab. This book is the result of our vision and goals. We have purposely included authors that are both pulmonary physicians and scientists, each with expertise in their field. We hope you find *Pulmonary Function Testing: Principles and Practice* ideally suited to your education and training in pulmonary physiology and how to perform and interpret PFTs.

Burlington, VT, USA

David A. Kaminsky
Charles G. Irvin

Acknowledgment

We dedicate this book to the memory of Reuben Cherniack, MD. Reuben was not only a world-class pulmonary physiologist but also a friend and mentor to both of us when we worked with him at National Jewish Health and the University of Colorado Health Sciences Center in Denver. Reuben inspired in us a love for pulmonary physiology and a desire to apply that knowledge for the benefit of patients with the most severe of lung disease. He continually challenged us to understand, teach, and perform PFTs at the highest level of excellence.

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Chapter 1
Introduction to the Structure and Function of the Lung

Jeff Thiboutot, Bruce R. Thompson, and Robert H. Brown

1.1 Pulmonary Structure

The primary function of the lungs is gas exchange. Knowledge of the anatomy and airflow pathways is important to understand how gas moves to the blood from the atmosphere. Human airway anatomy starts at the oro- and nasopharynx and terminates at the alveoli. The airways along this path can be divided into two zones: (1) conducting zone, consisting of large and medium airways that are responsible for mass transport of air from the atmosphere to the alveoli without gas exchange occurring, and (2) respiratory zone, consisting of small airways with alveolar sacs in their walls (airways <2 mm) and alveoli that participate in gas exchange with the blood.

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1.1.1 Conducting Zone

Air moves through the mouth and nares to the oro- and nasopharynx. The oro- and nasopharynx combine to form the hypopharynx which houses the epiglottis, larynx, and upper esophageal sphincter. The larynx is a complex structure that contains the vocal cords and forms a passage for movement of air from the hypopharynx to the trachea. The trachea is a flexible single tubular airway passage which is kept patent by a series of c-shaped collagenous rings. Between the rings are smooth muscle and fibroelastic tissue. The posterior wall of the trachea contains no cartilaginous support and is comprised of a longitudinally oriented membrane that contains smooth muscle (Fig. 1.1). The trachea is 10–12 cm in length and is divided into an upper extrathoracic portion and a lower intrathoracic portion, separated at the level of superior aspect of the manubrium. At the angle of Louis (manubriosternal junction), the trachea divides into the left and right main stem (primary) bronchi at the main carina. The main stem bronchi then rapidly branch into shorter, smaller (secondary) lobar bronchi, then (tertiary) segmental bronchi, and then subsegemental bronchi until terminating into bronchioles. Like the trachea, bronchi are flexible and contain less collagenous support than the trachea, and the folded mucosa is encircled by a layer of smooth muscle (Fig. 1.2). Tertiary bronchi give rise to the terminal component of the conducting system, bronchioles, which are generally less than 1 mm in diameter. Bronchioles do not contain collagenous support but contain folded mucosa with a ring of smooth muscle (Fig. 1.3). The most distal bronchioles are named terminal bronchioles and also contain a thin layer of smooth muscle (Fig. 1.4). Since no gas exchange occurs in the conducting zone, this entire region is considered anatomical dead space (see Chap. 5), the total volume of which is ~150 mL.

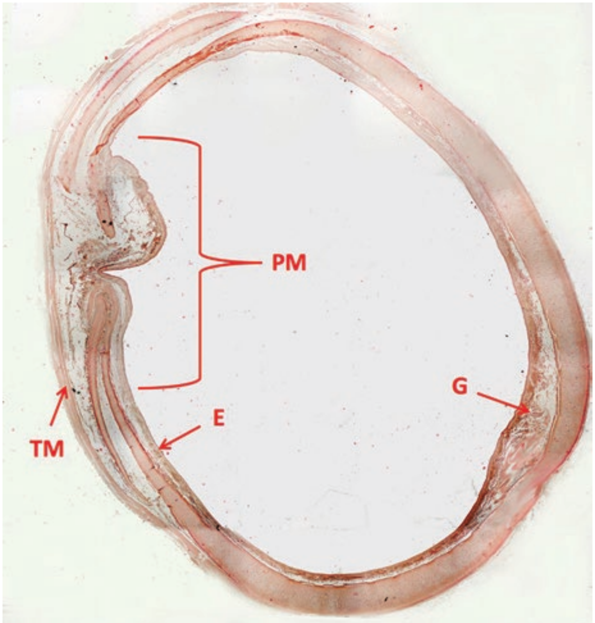

Fig. 1.1 Trachea histology. PM posterior membrane, TM trachealis muscle, G glands, E epithelium

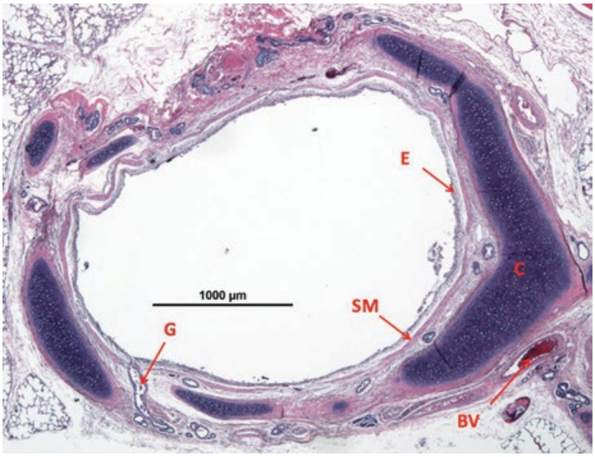

Fig. 1.2 Bronchus histology. Cross section of bronchus depicting microstructure of the airway wall. SM smooth muscle, C cartilage, G gland, BV blood vessel (bronchial circulation), E epithelium

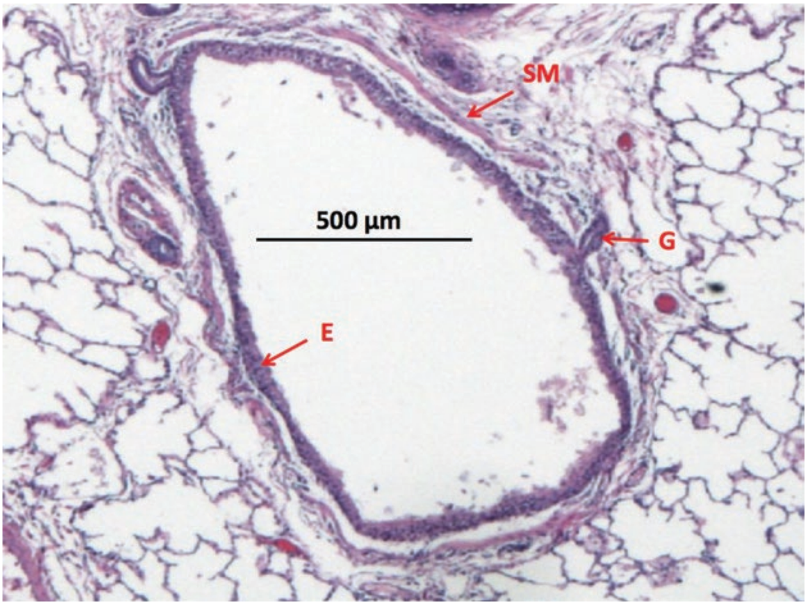

Fig. 1.3 Bronchiole histology. SM smooth muscle, G gland, E epithelium

1.1.2 Respiratory Zone

The respiratory zone begins as terminal bronchioles and subsequently divides into respiratory bronchioles forming anatomical units called acini. While respiratory bronchioles are still conducting airways, they contain alveolar sacs that can participate in gas exchange. The respiratory bronchioles divide into alveolar ducts that are completely lined with alveolar sacs. The alveolar ducts terminate with thin walled