SECOND EDITION

Equipment for Respiratory Care

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19629-0

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Cover Design: Scott Moden
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Cover Image (Title Page, Part Opener, Chapter Opener): © SidorArt/Shutterstock
Printing and Binding: LSC Communications

Library of Congress Cataloging-in-Publication Data
Names: Volsko, Teresa A., editor. | Chatburn, Robert L., editor. | El-Khatib, Mohamad F., editor.
Title: Equipment for respiratory care / edited by, Teresa A. Volsko, Robert L. Chatburn, Mohamad F. El-Khatib.
Description: Second edition. | Burlington, Massachusetts : Jones & Bartlett Learning, [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2020007426 | ISBN 9781284196221 (paperback)
Subjects: MESH: Respiratory Therapy--instrumentation | Respiratory Tract Diseases--therapy
Classification: LCC RC735.I5 | NLM WF 26 | DDC 615.8/3620284--dc23
LC record available at https://lccn.loc.gov/2020007426

6048

Printed in the United States of America
24 23 22 21 20 10 9 8 7 6 5 4 3 2 1

Dedication

I dedicate this book to the respiratory students whose quest for knowledge inspired me to find new and innovative ways to maximize their educational experience and to my family, whose love and support allowed me to pursue my dreams!

Teresa A. Volsko

Learning and teaching are fundamental to existence. I dedicate this book to all those who understand that to achieve extraordinary results you must live an uncommon life.

Robert L. Chatburn

To Mayssa, Farouk, Dina, and Manar—thanks for your love and support. You are the joy of my life.

To my mother, Souad, and to the soul of my father.

Mohamad F. El-Khatib

Brief Contents

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Foreword

Throughout my career, I have found that airway management is the major role of the respiratory therapist, whether opening and maintaining a closed airway or sustaining breathing through mechanical ventilation. With this role comes an expectation of being the expert on all the equipment that is needed to maintain an airway and provide ventilation. This expertise is what sets respiratory therapists apart from other hospital personnel. Biomedical engineers know how equipment works by its mechanical design, and anesthesia personnel know how to ventilate patients in the controlled environment of the operating room. But troubleshooting skills and knowledge of airway and ventilation equipment separate the respiratory care professional from these other professionals.

Troubleshooting is an important skill for any respiratory therapy student to learn and for all practicing respiratory therapists to maintain. Troubleshooting involves locating and correcting technical problems related to the machinery used in patient care. Under most circumstances, this requires logical reasoning, as opposed to problem posing and problem solving. Troubleshooting is always essential in clinical practice because members of the medical team in the ICU rely on respiratory therapists' technical expertise to advise, explain, and troubleshoot equipment used for airway management and mechanical ventilation. Respiratory therapists work in teams, but there are times when they must work without assistance. It is in such circumstances that troubleshooting respiratory care equipment is most crucial. The topic of troubleshooting in respiratory therapy is taught at a level that cannot be found in the core curriculum of medical or nursing schools. Thus, it is a unique skill of respiratory therapists that is not shared by other allied health clinicians, nurses, and physicians.

This new text covers most equipment topics addressed in respiratory therapy education. Respiratory therapy equipment courses are usually among the first courses in most respiratory therapy programs of study. Teresa A. Volsko, Robert L. Chatburn, and Mohamad F. El-Khatib bring their expertise and insights to the operation and indications for use of equipment used in respiratory care practice. The text provides information that builds on the respiratory therapist's knowledge of the physiology of the respiratory system as well as the electronic functionality of the equipment used while experience is gained in the laboratory setting and on the job. I hope that students and practitioners alike will use this information and ask themselves, "How well do I use my troubleshooting skills when I work without assistance in my practice, for instance, when I make a home visit to a patient receiving mechanical ventilation?" Our future patients are depending on us to be able to answer this question!

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Preface

Technological advances have made a significant impact on our profession. The equipment used to treat disorders of the respiratory tract are no longer simple machines. Many of the devices respiratory therapists use are governed by sophisticated operating systems.

In this new edition, the authors recognize that it is not just about the technology; it's about sharing knowledge and the key elements of information that will enable respiratory care professionals to distinguish between equipment malfunction and patient intolerance in order to effectively communicate recommendations for therapy or changes to the plan of care. The authors embraced this work as a mechanism to build a learning community and create a culture of professionalism.

The layout of each chapter is standardized, much like the format for a scientific research paper. Just as scientific papers commence with a thorough review of the literature, each chapter provides the reader with a purpose for the particular topic. The information from a variety of sources is summarized in a logical and uniform fashion to provide equipment specifications, routine use, and limitations. Rather than outlines of manufacturer specifications, the authors provide fundamental theoretical constructs for the categories of equipment described in each chapter.

Finally, there is an in-depth discussion that ties in the clinical significance of the equipment presented. Similar to the discussion section of a scientific manuscript, this portion of the chapter establishes the practical relevance of the equipment discussed. The equipment selection and troubleshooting guides provide practical solutions to complex problems. These sections are presented in an easy-to-follow manner and provide the theoretical constructs, practical applications, and algorithms to provide respiratory care students and professionals with the tools to distinguish equipment malfunction from patient intolerance. Understanding this difference is an essential critical thinking skill and instrumental when communicating with the interdisciplinary team. These skills are necessary to clearly articulate the need to initiate therapy or a rationale for recommending modifications to the patient plan of care.

Chapter-by-Chapter Overview

The text is written in a clear and concise manner. Illustrations, tables, and figures are provided to enhance the learning experience.

Chapter 1, Introduction to Medical Gases, introduces the learner to the essential role medical gases play along the continuum of care. Essential elements in the selection, distribution, storage, and safe handling of medical gases are presented. This chapter also highlights the safety standards required by credentialing bodies, such as the Joint Commission and the National Fire Protection Agency, that impact our clinical practice.

Chapter 2, Administering Medical Gases, provides clinically relevant information on the delivery systems and devices used to administer medical gas therapy. This chapter provides a comprehensive review of the different delivery devices that are used to administer medical gases along the continuum of care. It also explores the ongoing debate regarding the best methods to safely deliver medical gases. Practical information, rooted in the evidence available in the literature, is presented to facilitate a systematic thinking approach to device selection.

Chapter 3, Hyperbaric Oxygen Therapy, explores the fascinating and rapidly expanding field of hyperbaric oxygen therapy. Because application of this therapeutic modality requires knowledge of the physics of gases, gas laws as well as different oxygen delivery systems are presented. This chapter also discusses the physiologic principles of hyperbaric oxygen as well as its indications, contraindications, complications, and hazards. A discussion of the different chambers, equipment, and monitoring used to evaluate oxygenation and ventilation as well as the use of concurrent mechanical ventilation is presented.

Chapter 4, Humidity and Aerosol Therapy, presents the principles of humidity and aerosol therapy. This chapter describes the various devices that are currently used in the clinical practice of providing humidity and aerosol therapies in spontaneously breathing and mechanically ventilated patients. Information is provided to enable the learner to gain a firm understanding of the rationale, physiologic basis, indications, and contraindications for humidity and aerosol therapies. Additionally, this chapter provides information in a manner that facilitates comprehension of the technical considerations germane to the multitude of devices available for clinical use.

Chapter 5, Medicated Aerosol Delivery Devices, details the operational characteristics of a variety of

devices used to deliver medication to the lung. This chapter also provides information on devices designed specifically for certain medications. An understanding of the function and limitations of medicated aerosol delivery devices will enable respiratory therapists to appropriately select the device or devices that can make a positive clinical impact.

Chapter 6, Airway Management and Emergency Resuscitation Equipment, provides a clinical approach to the devices used to secure and maintain a patent airway. Because any device has the potential to help as well as cause harm, this chapter is designed to familiarize the learner with the indications, proper use, and limitations of airway management equipment. A practical approach to evaluating the plethora of equipment used in the routine and emergency care of the airway is also provided.

Chapter 7, Blood Gas and Critical Care Analyte Analysis, focuses on the equipment used for blood gas and analyte analysis. The types of equipment available in core labs and point-of-care testing are highlighted. The importance of implementing a quality management system to maintain the integrity of a sample and assure accuracy of results is detailed. Regulatory requirements from agencies such as the College of American Pathology and the Joint Commission as well as federal requirements, such as the Clinical Laboratory Improvement Amendments of 1988, are detailed.

Chapter 8, Patient Monitors, provides relevant information on noninvasive equipment used to measure and monitor clinical parameters important to the diagnosis and retreatment of cardiorespiratory system disorders. The appendices provide a unique way to compare performance characteristics and evaluate the utility and limitations of noninvasive monitors used for monitoring oxygen saturation and expired carbon dioxide concentrations as well as mechanisms for identifying and quantifying hemoglobin disorders. This chapter also provides a comprehensive review of equipment available for the evaluation and monitoring of lung mechanics.

Chapter 9, Measuring and Monitoring Pulmonary Function, describes types of devices used to evaluate and monitor pulmonary health. Stationary instruments used in a laboratory as well as portable devices and those used at the bedside and in ambulatory and home care settings are characterized by their measurement methods. A comparison of methods to select devices that are useful in detecting airflow limitations, gas transfer impairment, volume limitations, and respiratory muscle weakness is provided. This chapter also highlights how a quality management system can improve performance standards and comply with regulatory requirements for training personnel and performing quality control procedures.

Chapter 10, Mechanical Ventilation, presents a unique and systematic approach to a complicated subject. The fundamental theory for understanding ventilator terminology is presented in a way that leads to a practical taxonomy for modes of ventilation. This approach facilitates the understanding of ventilator operation that transcends a mere proliferation of the trade names of the modes, minimizing confusion and the propensity for user error. Through the use of this taxonomy, the learner is able to classify, compare, and contrast the functional differences of the nearly 300 modes currently available on mechanical ventilators.

Chapter 11, Sleep Apnea Devices, provides clinically relevant information on the devices available for the treatment of sleep-disordered breathing. The principles of operation, safety, and technical considerations used for patient selection are provided. Key aspects of cleaning and maintenance as they relate to the safe and effective operation of these devices in the long-term care and home care environment are detailed.

Chapter 12, Cardiovascular Monitoring, focuses on the equipment used to monitor and assess the function of the cardiovascular system. The variety of devices used for cardiovascular monitoring, from the electrocardiogram to the devices that measure intravascular pressures and cardiac output, are discussed. The clinical relevance of hemodynamic monitoring for mechanically ventilated patients is highlighted. In addition to the theory of operation, this chapter familiarizes the learner with techniques used to troubleshoot technological problems.

Chapter 13, Hyperinflation Therapy, describes the devices used to perform lung expansion maneuvers, which are those that subject the lungs to volumes greater than normal in order to reinflate areas of collapse and improve gas exchange. Incentive spirometers; intermittent positive pressure breathing devices; and positive airway pressure devices, including positive expiratory pressure devices used to accomplish hyperinflation therapy goals, are detailed.

Chapter 14, Airway Clearance, focuses on the mechanical devices used to clear airway secretions. Mechanical devices that assist with the cephalad mobilization of secretions in airways as well as those that assist with expectoration are discussed. Although some of the devices that are described in this chapter are also found in Chapter 12, the dual function of these devices and their operational characteristics that enable them to generate volumes greater than normal and expiratory flow rates that can move airway secretions cephalad are explored.

Chapter 15, Manual and Automatic Resuscitators, differentiates automatic resuscitators from mechanical ventilators and provides clinically relevant information on the different types of resuscitators available for manual ventilation. Key aspects for device use and selection are provided.

The authors of this textbook are distinguished educators, practicing clinicians, researchers, and internationally recognized experts in both pediatric and adult

respiratory care. These authors have a passion for educating respiratory therapists, from the novice to the advanced practitioner, in order to optimize care, improve outcomes, and advance the practice of our profession. Their contributions will serve respiratory care students as well as credentialed practicing clinicians.

What's New to This Edition

- Expanded descriptions of interfaces used for oxygen delivery (i.e., Oxymask) as well as devices used to administer heated high-flow oxygen therapy
- A schematic breakdown of the control panel and injector used to deliver inhaled nitric oxide
- A comprehensive description of the heated pass-over and wick humidifiers
- Expanded use of illustrations for tracheal tubes and more detailed product descriptions
- Additional illustrations and product descriptions of various devices available for point-of-care blood gas and analyte testing
- A description of brain tissue oxygen monitoring systems
- Comprehensive details on the type of pulmonary function equipment, capabilities, and software and quality control used in the lab, in the ambulatory setting, or at the bedside

How to Use This Book

Chapter Features

- Each chapter of the book begins with a list of **Chapter Objectives** to help you focus on the most important concepts in that chapter.

OBJECTIVES

1. Define a medical gas.
2. Describe the types of gases used in respiratory care.
3. Explain how medical gases are delivered to the patient.
4. Describe how liquid oxygen is formed.
5. Describe how liquid oxygen is delivered to the patient.
6. Differentiate between liquid and compressed gas.
7. Describe the piping system used in acute care facilities.
8. Discuss the use of station outlets and the types of connectors used.
9. Explain the various methods of testing the hospital gas distribution system.
10. Identify problems with a hospital piping system.
11. Discuss how medical gases are stored and transported.
12. Identify the various cylinder sizes and colors and how they relate to the particular medical gas contents.
13. Discuss how oxygen concentrators work.

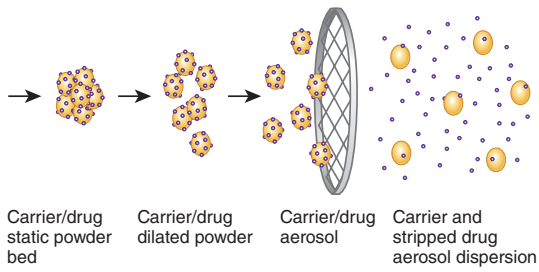
- Each chapter contains **Tables** that highlight important information, such as **Table 6-20** Endotracheal Tube Exchangers.

TABLE 6-20
Endotracheal Tube Exchangers

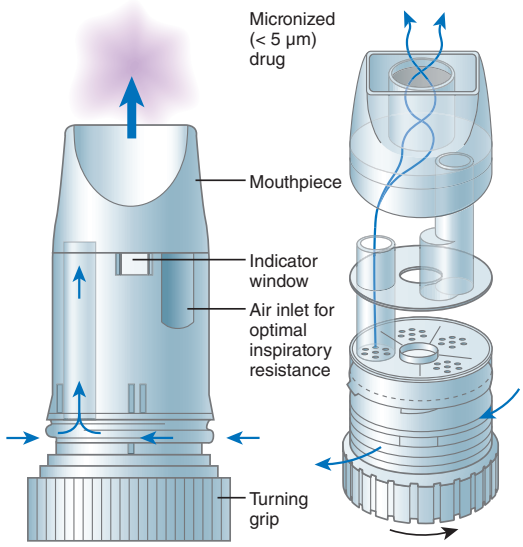
Brand	OD (mm)	ETT Range (ID, mm)	Length (cm)	Use
Sheridan TTX	2.0 3.3 4.8 5.8	2.5–4 4–6 6–8.5 7.5–10	56 81 81 81	Regular tube exchange
Sheridan ETX		35–41 Fr	100	Double lumen tubes
Sheridan JETTX		6.5–10	100	Provide jet ventilation or oxygen delivery
Cook Airway Exchanger Soft Tip and Extra Firm	11 Fr 14 Fr	≥4 ≥5	100 100	Provide jet ventilation or oxygen delivery; extra firm is for double lumen tubes
Cook Airway Exchange Catheter Regular	8 11 14 19	≥3 ≥4 ≥5 ≥7	45 83 83 83	
Aintree Intubation Catheter	19	≥7	56	

OD, outer diameter; ETT, endotracheal tube; ID, inner diameter.

- This text is **highly illustrated** with diagrams and photos demonstrating a variety of concepts, including **Figure 5-24** **A.** Aerosolization of dry powder. **B.** Component parts of Flexhaler. **C.** Component parts of Diskus.



(A)



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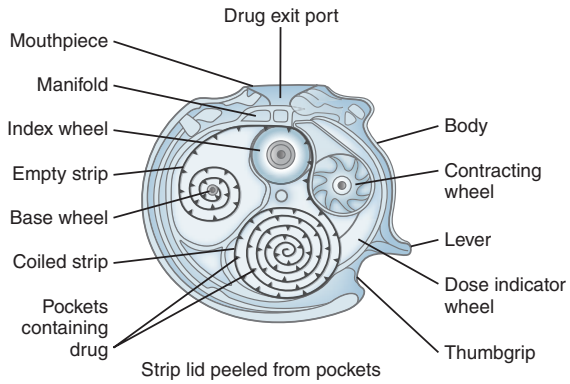

(C)

FIGURE 5-24 **A.** Aerosolization of dry powder. **B.** Component parts of Flexhaler. **C.** Component parts of Diskus.

A. Modified from Dhand R, Fink JB. Dry powder inhalers. Respir Care 1999;44:940-951. **B.** Reproduced with permission from Crompton GK. Delivery systems. In: Kay AB, editor. Allergy and allergic diseases. London: Blackwell Science; 1997:1440-1450; permission conveyed through Copyright Clearance Center, Inc.

Instructor and Student Resources

For the Instructor

As a benefit of using this textbook and to save you valuable time in the preparation and instruction of this course, you will receive access to

- Slides in PowerPoint format
- Image bank
- Test bank
- Prepopulated midterm and final exams
- Sample syllabus
- Answer key to student activities
- Web links to computer-aided instructional materials to enhance the learning experience and ensure that the content is current and relevant to clinical practice as well as online resources for students and faculty, which include:
  - AARC expert panel and evidence-based clinical practice guidelines
  - Comprehensive resources for medicated aerosol delivery
  - Practice guidelines from professional organizations

For the Students

- Laboratory exercises were designed to complement didactic instruction by providing reinforcement and opportunities to realistically simulate clinical scenarios and interdisciplinary team rounds.
- Case studies present scenarios and assessment items so students can apply their knowledge to real-life situations.
- Access to our interactive Equipment Simulator allows students to realistically simulate clinical scenarios and interdisciplinary team rounds.

About the Authors

Teresa A. Volsko, MHHS, RRT, FAARC, is adjunct graduate faculty for Rush University and Northeastern Medical College of Ohio and a fellow of the American Association for Respiratory Care. Currently, Terry is the director of Respiratory Care, Transport, and the Communication Center for Akron Children's Hospital. Before joining the Akron Children's Hospital, Terry was an associate professor of health professions in the Bitonte College of Health and Human Services at Youngstown State University. She served as the program director for the Respiratory Care and Polysomnography programs for several years. Terry is the author of 3 textbooks, more than 40 manuscript publications in peer-reviewed medical journals and several book chapters. She has served the profession in many capacities and is currently a member of the Board of Trustees for the National Board for Respiratory Care, Board of Trustees for the American Respiratory Care Foundation, Board of Directors for Lambda Beta, the American Association for Respiratory Care Evidence-Based Clinical Guidelines Committee. Terry is also a member of the Editorial Boards of *Respiratory Care Journal* and the *Canadian Journal for Respiratory Therapy*.

Terry was born and raised in the Youngstown, Ohio, area. She received her associate degree in respiratory therapy technology, her Bachelor of Science, Master of Health and Human Services and Master of Business Administration from Youngstown State University. Terry's passion for the respiratory care profession and dedication to mentoring respiratory care students and professionals span nearly four decades.

Robert L. Chatburn, MHHS, RRT-NPS, FAARC, is a professor in the Department of Medicine at Lerner College of Medicine of Case Western Reserve University and a fellow of the American Association for Respiratory Care. Rob is currently the clinical research manager, Section of Respiratory Therapy, at the Cleveland Clinic. Previously he was the technical director of respiratory care at University Hospitals for 20 years. He is the author of nine textbooks and over 300 publications in peer-reviewed medical journals. He is a member of the Editorial Board of *Respiratory Care Journal* and is recognized internationally for his contributions to mechanical ventilation research.

Rob, a native of Niles, Ohio, spent his career in the Cleveland, Ohio, area. He received an associate degree from Cuyahoga Community College and Bachelor of Science and Master of Health and Human Services degrees from Youngstown State University. He started his career at Rainbow Babies and Children's Hospital in 1977. In 1979, he was promoted to research coordinator. In 1986, he took the position of technical director of pediatric respiratory care and, in 1995, annexed the adult division as well. In 1997, he became assistant professor of pediatrics at Case Western Reserve University and was promoted to associate professor in 1998. In 2006, Rob became clinical research manager, Section of Respiratory Therapy, at the Cleveland Clinic. Rob became a fellow of the American Association for Respiratory Care in 1998 and was a recipient of the Forrest M. Bird Lifetime Scientific Achievement Award and Jimmy Young Medal.

Mohamad F. El-Khatib, MD, PhD, MBA, RRT, is a professor of anesthesiology and the director of the Respiratory Therapy Department at the American University of Beirut Medical Center. Dr. El-Khatib has published more than 115 peer-reviewed articles and abstracts in the fields of anesthesiology, critical care medicine, and respiratory care. Dr. El-Khatib's main area of interest is optimization of mechanical ventilation, including newer and nonconventional modes of ventilatory support and strategies for liberation from mechanical ventilation. Dr. El-Khatib has lectured at many international and regional meetings. He is currently the managing editor of the *Middle East Journal of Anesthesiology* and a reviewer for the journals of *Critical Care Medicine*, *Respiratory Care*, *Critical Care*, *American Journal of Respiratory and Critical Care Medicine*, *Lung*, and *Saudi Journal of Anesthesia*.

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