SECOND EDITION

Respiratory Care
Patient Assessment and Care Plan Development

David C. Shelledy
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Dedication

To my wife, Maga, the light of my life, whose love and support makes this possible, and my wonderful daughter, Jennifer. I am very proud of you both.

—DCS

Dedicated to my wife, Jean, and my daughter, Emilee, who are my inspiration; and the support of my Pulmonary/Critical Care Medicine Division, who are truly my second family.

—JIP

Brief Contents

Contents

Preface

This text was created for students and clinicians who are concerned with the assessment and care of patients with cardiopulmonary disorders to provide a comprehensive guide to patient evaluation and implementation of appropriate, evidence-based respiratory care plans. We are delighted to be able to provide this second edition of this popular text, which has been designed to provide the most current and up-to-date information available to respiratory therapists and others involved in the care of patients with cardiopulmonary disease.

Chapter Breakdown

The text has a natural flow. It begins by describing the purpose of patient assessment (Chapter 1) and methods associated with evidence-based practice. Critical diagnostic thinking is reviewed and then applied to the development and implementation of respiratory care plans (Chapter 2). The text then guides the reader through the review of existing data in the medical record (Chapter 3), the patient interview (Chapter 4), the physical assessment of the patient (Chapter 5), and the ordering and evaluation of the diagnostic studies needed.

Chapters 6 through 8 focus on the assessment of oxygenation, ventilation, and arterial blood gas sampling and interpretation. Chapter 9 reviews laboratory studies related to hematology, clinical chemistry, microbiology, assessment of sputum, urinalysis, skin testing, histology and cytology, and molecular diagnostics. In Chapter 10, electrocardiogram (ECG) monitoring and interpretation are discussed, including findings with specific cardiac disorders. Chapter 11 focuses on imaging techniques, including the chest radiograph, computed tomography (CT) scan, magnetic resonance imaging (MRI), ultrasonography, and other imaging studies used in the evaluation of the respiratory care patient and includes the evaluation of imaging findings associated with specific pulmonary diseases. Pulmonary function testing is described in Chapter 12, including the evaluation of patients with obstructive and restrictive disease.

Chapter 13 details diagnostic bronchoscopy and other diagnostic studies. Acute and critical care monitoring, with a focus on the patient receiving mechanical ventilatory support, is covered in Chapter 14. Chapter 15 addresses the use of sleep studies in the evaluation of the cardiopulmonary patient. Last, but not least, Chapter 16 covers maternal, perinatal/neonatal, and pediatric patient assessment.

What's New

All of the book chapters have been carefully updated to include the most current medications, treatment protocols, equipment, and techniques. For example:

- The care of patients with asthma and COPD have been updated based on the most current Global Initiative for Asthma (GINA) and Global Initiative for Chronic Obstructive Lung Disease (GOLD) recommendations.
- Recognition of the impact of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease 2019 (COVID-19) has been incorporated throughout with respect to patient assessment and care.
- Appendix A has been updated to provide a guide for text materials keyed to the most current National Board for Respiratory Care (NBRC) Therapist Multiple Choice Examination and Clinical Simulation Examination content outlines.
- An extensive new section (Appendix B) has been added to provide a synopsis of the major cardiopulmonary disease states and conditions that the respiratory care clinician will encounter. This new section provides the description, etiology, clinical manifestations, diagnosis, and treatment of major diseases and disorders and provides a quick reference for respiratory therapists and others as they complete their assessment and care plans.
- Appendix C provides an updated list of commonly used abbreviations.

How to Use This Book

- **Clinical Focus** The Clinical Focus exercises are designed to help the reader refine his or her critical thinking and problem-solving skills. They serve as short case studies with problems for the reader to solve. They can be used for individual study, as course assignments, or as part of a robust class discussion.

CLINICAL FOCUS 4-1 Smoking Cessation

Upon patient interview, the respiratory care clinician finds that the patient has smoked for 30 years, starting smoking at age 16. The patient typically smokes two packs of cigarettes per day and has a chronic cough, with about a tablespoon of sputum produced per day. The clinician advises the patient that she must quit smoking and informs the patient of the consequences of not quitting. The patient states that she wants to quit smoking, but that she has been unsuccessful in past attempts to quit. What should the clinician now do?

The clinician has completed the first three As of smoking cessation: *ask, advise,* and *assess*. The patient seems ready to stop smoking. The next steps are to *assist* the patient in the quit attempt and to *arrange* for follow-up care. Types of assistance should include helping the patient to develop a quit plan and providing recommendations of approved medications (see Table 4-15). One medication that may be useful is varenicline tartrate (Chantix). Medication should be started 1 week before the set quit date and continued as follows:

- Starting week: 0.5 mg once daily on days 1 through 3 and 0.5 mg twice daily on days 4 through 7.
- Subsequent weeks: 1 mg twice daily for a total of 12 weeks.
- An additional 12 weeks of treatment is recommended for those who are successful to increase likelihood of long-term abstinence.

Dose should be reduced in patients with renal impairment and in patients who cannot tolerate adverse effects.

Practical counseling should be provided, as well as treatment and social support in the clinical environment.

Finally, the respiratory care clinician should arrange for follow-up care (see Table 4-14).

- **RC Insights** Interspersed throughout the text, RC Insights provide the clinician with useful tips on patient assessment and management.

RC Insight

Although wheezing is a hallmark of asthma, there are many other possible causes, including postnasal drip, vocal cord disorders, airway tumors, interstitial lung disease, occupational lung disease, and bronchiolitis.

- **Tables** highlight important information in each chapter.

TABLE 5-7
Ramsay Sedation Scale

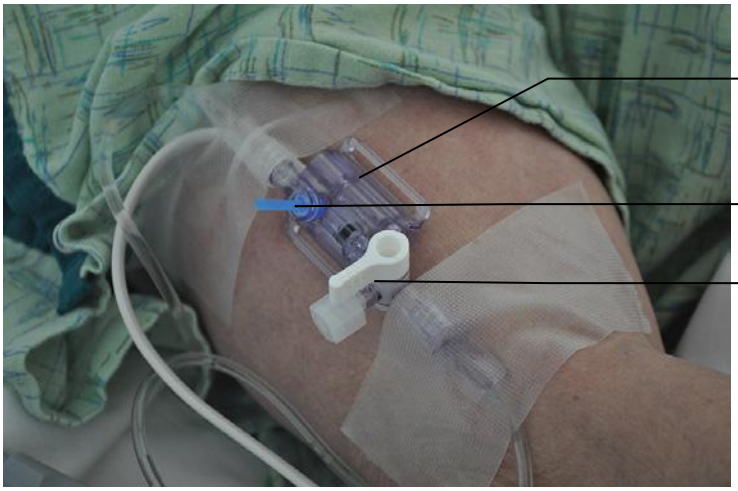
The Ramsay Sedation Scale rates the patient's sedation/agitation level from minimal sedation/high agitation (score = 1) to maximum sedation (score = 6). A score of 2 points would be preferred in most patients.

Level	Response
1	Anxious, agitated, restless
2	Cooperative, oriented, tranquil
3	Responding to commands only
4	Asleep, brisk response to stimulus
5	Asleep, sluggish response to stimulus
6	Unarousable/patient exhibits no response

Information from Stanford School of Medicine | Palliative Care. Ramsay sedation scale. Available at https://palliative.stanford.edu/palliative-sedation/appendices/ramsay-sedation-scale/. Accessed August 21, 2020.

- This text is **highly illustrated** with diagrams and photos that demonstrate a variety of concepts.

(A)



(B)

FIGURE 8-8 **A.** Radial artery monitoring system for a patient in the intensive care unit. **B.** Close-up of transducer, flush valve, and stopcock with sample port.

- **Key Points** Listed at the conclusion of each chapter, the Key Points provide a summary of the important facts and concepts that students should learn. It provides a helpful study tool.

Key Points

- Symptoms of hypoxia include excitement, overconfidence, restlessness, anxiety, nausea, headache, and shortness of breath.
- Signs of hypoxia include tachycardia, tachypnea, hypertension, impaired judgment, confusion, disorientation, and signs of respiratory distress.
- Severe hypoxia may cause bradycardia; hypotension; slowed, irregular breathing; and loss of consciousness.
- Cyanosis is not a reliable indicator for the presence or severity of hypoxia.
- Hypoxemic respiratory failure ("lung failure") is inadequate arterial oxygenation as assessed by Pa_{O_2}, Sp_{O_2}, and/or Sa_{O_2}.
- Factors that determine inspired oxygen tension are barometric pressure and oxygen concentration (F_{IO_2} or $\%O_2$).
- Mountain sickness may affect hikers, skiers, mountain climbers, or travelers to high-altitude locations.
- Severe cases of mountain sickness may lead to high-altitude cerebral edema (HACE) and/or high-altitude pulmonary edema (HAPE).
- In-flight supplemental oxygen is recommended for patients who may otherwise develop a Pa_{O_2} <50 to 55 mm Hg during air travel.
- Ambient hypoxia may occur with industrial accidents and inhalation of asphyxiant gases.
- Causes of upper airway obstruction include secretions, edema, trauma, foreign bodies, and tumors.
- Bronchospasm, mucosal edema, and secretions in the lower airways may impair oxygenation.
- Upper airway obstruction may be classified as fixed or variable based on pulmonary function testing.
- Causes of airway obstruction in children include epiglottitis and croup.
- Obstructive lung diseases include asthma, COPD, emphysema, chronic bronchitis, bronchiectasis, and cystic fibrosis.
- Pa_{CO_2} is determined by alveolar ventilation and CO_2 production.

- **Appendix A:** Patient Assessment and the National Board for Respiratory Care (NBRC) Examinations provides a guide to the book's content that will be needed to successfully pass the National Board for Respiratory Care Therapist Multiple-Choice Examination and the Clinical Simulation Examination. Because of its comprehensive nature, we believe this book will also be of great value to individuals preparing for the examinations administered by the National Board for Respiratory Care.
- **Appendix B** Synopsis of Cardiopulmonary Disease. This new section provides a quick reference for respiratory therapists and others regarding the description, etiology, clinical manifestations, diagnosis, and treatment of the major cardiopulmonary diseases and disorders.
- A brief note on the use of **abbreviations**:
  - *aka* is used in place of "also known as."
  - *e.g.*, is the abbreviation for the Latin phrase, exemplī grātia, which means "for example."
  - *i.e.*, comes from the Latin phrase *id est*, which means "that is" or "in other words."
- **Appendix C** provides an expanded list of commonly used medical abbreviations.

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 the following:

- Slides in PowerPoint format
- Image bank
- Test bank
- Sample syllabus
- 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

For the Students

- Animations are embedded in the eBook to illustrate key concepts from the text.

Note from the Authors

Respiratory care may be defined as the healthcare discipline that specializes in the promotion of optimum cardiopulmonary function and health. It is specifically focused on the assessment, diagnostic evaluation, treatment, and care of patients with deficiencies and abnormalities of the cardiopulmonary system. Respiratory care clinicians must also attend to the prevention of cardiopulmonary disease and the management of patients with chronic disease. Thus, the scope of respiratory care extends to the patient, the patient's family, and public education. Respiratory care patient assessment and care plan development may be provided by physicians, advanced practice nurses, physician assistants, and respiratory therapists. Respiratory therapists apply scientific principles to prevent, identify, and treat acute or chronic dysfunction of the cardiopulmonary system. Although this book is primarily aimed at providing the advanced practice respiratory therapist with the knowledge and skills needed to perform patient assessment and develop appropriate respiratory care plans, we believe that the information contained will be of great value to those who prescribe respiratory care and for all healthcare practitioners interested in optimizing outcomes for patients with heart and lung disease. Throughout the text we use the term *respiratory care clinician* to refer to the healthcare practitioners who, as part of the interprofessional team, provide assessment, treatment, and care of patients suffering from heart and lung disorders.

It is our hope that this book will allow the reader to bridge the gap between patient assessment and treatment. Evidence-based practice and critical diagnostic thinking are applied to specific patient situations. The reader will learn how to apply assessment skills to the development, implementation, and evaluation of respiratory care plans. The text should also be of great value to individuals preparing for the examinations administered by the National Board for Respiratory Care.

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CHAPTER

1

Introduction to Patient Assessment

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CHAPTER OUTLINE

CHAPTER OBJECTIVES

1. Define *respiratory care*.
2. Explain the rationale for respiratory care–related patient assessment.
3. Describe each of the components of a complete patient assessment (history, physical, laboratory tests, imaging studies, and other diagnostic tests).
4. Explain specific factors that determine individual health.
5. Describe the social determinants of health, and explain the importance of addressing healthcare disparities.
6. List the major causes of death in the United States.
7. Explain the "triple aim" of healthcare.
8. Describe each of the main drivers of the healthcare system (quality, access, and cost).
9. Explain the impact of misallocated care.
10. Describe evidence-based practice.
11. Evaluate sources of evidence.
12. Describe an approach to critical diagnostic thinking.
13. Describe the presentation of common respiratory diseases and disorders.

KEY TERMS

activity of daily living (ADL)
acute respiratory distress syndrome (ARDS)
arterial blood gas (ABG)
asthma
case-control study
chronic bronchitis
chronic obstructive pulmonary disease (COPD)
cohort study
critical thinking
emphysema
evidence-based practice (EBP)
health
healthcare disparity
health-related quality of life (HRQOL)
history
meta-analysis
misallocation
obstructive lung disease
patient outcome
physical examination
pneumonia
pulmonary function testing (PFT)
randomized controlled trial (RCT)
respiratory care
restrictive lung disease
sign
social determinant of health (SDOH)
symptom
triple aim
value-based care
vaping

Overview

This chapter introduces respiratory care patient assessment to include the rationale, importance, and key components of the assessment process. An overview of health issues in the United States is provided, and the skills needed for evidence-based practice, critical diagnostic thinking, and respiratory care plan development are introduced. Assessment techniques for hypothesis formulation and evaluation, to include identifying and gathering needed information and evaluation of patient problems, are provided. Typical presentations of common respiratory disease states and conditions are reviewed.

Introduction to Patient Assessment

Respiratory therapists, nurses, and physicians are intimately involved in the diagnosis, treatment, care, and follow-up evaluation of patients with heart and lung problems. **Respiratory care** has been defined as "the healthcare discipline that specializes in the promotion of optimum cardiopulmonary function and health and wellness. Respiratory therapists employ scientific principles to identify, treat, and prevent acute or chronic dysfunction of the cardiopulmonary system."[1] Modern healthcare demands that all patients receive the right care at the right time and that unnecessary or inappropriate care be reduced or eliminated. In addition, care should promote patients' health and well-being and prevent, when possible, the development of acute and chronic disease. The goal is **value-based care**, which seeks to improve health, reduce the effects and incidence of chronic disease, control cost, and allow patients to live healthier lives.[2] All of these goals demand excellent patient assessment skills.

RC Insight

Value-based healthcare is a delivery model in which providers are paid based on quality rather than quantity of care provided. The goal is to improve health outcomes, while controlling cost where value is defined as quality divided by the cost of care.

Respiratory care patient assessment can be divided into three key areas: history, physical examination, and diagnostic testing (laboratory tests and imaging studies). Following initial assessment, hypotheses are formulated and evaluated regarding the patient's problem(s) and the respiratory care plan is developed and implemented.

We begin the assessment process with the patient interview, or **history**. This is where we determine the patient's perceptions of his or her health problem(s), as well as what the patient is experiencing (i.e., **symptoms**). Special emphasis should be placed on noting the difference between the patient's baseline symptoms and current symptoms. We review the patient's past medical history, as well as factors that may affect health, such as smoking, drug and/or alcohol use, nutrition, weight, fitness, occupation, environmental exposures, and family health problems. The patient interview is the first and most important step in identifying the problem. The physical assessment follows and includes observation of the patient (inspection) and his or her level of comfort or distress, auscultation (listening), palpation (touching), and percussion (thumping). Vital signs (i.e., pulse, respirations, blood pressure, and temperature) are measured, and pulse oximetry may be used to assess arterial blood oxygen saturation (Spo_2). During the physical assessment, we look for the presence (or absence) of **signs** associated with specific disease states or conditions. The **physical examination** helps us to clarify the patient's problem and guides us in gathering additional information.

Next, we consider diagnostic testing, including laboratory and imaging studies, and gather additional information to further clarify the patient's problem. Laboratory studies may include **arterial blood gases (ABGs)**, pulmonary function tests, blood chemistry, hematology, lipids, blood sugar, microbiology, and cardiac enzymes. Point-of-care testing (POCT) has become increasingly popular and includes assays useful in evaluation of patients for the presence of strep throat, influenza, anemia, lipid disorders, diabetes, and acute cardiac conditions, to name a few. POCT is performed at the site of patient care and the rapid turnaround of results can enable immediate diagnosis.[3]

Imaging studies may range from the standard chest radiograph to computed tomography (CT), magnetic resonance imaging (MRI), and diagnostic medical sonography (ultrasound). Point-of-care ultrasound (POCUS) refers to the use of highly portable ultrasound imaging equipment employed by clinicians at the bedside or in the clinic. POCUS is commonly used in the emergency department (ED) and intensive care unit for rapid detection and evaluation of a wide range of disorders including respiratory failure, trauma, cardiac disorders, deep vein thrombosis (DVT), pleural effusion, and pneumothorax. POCUS is often used to guide invasive procedures, such as pleural drainage, arterial cannulation, and placement of central venous catheters.[4,5]

Following completion of the history, physical exam, and any diagnostic studies, we begin to formulate and test hypotheses and develop a patient care plan. What do the history and physical suggest? Do the laboratory and imaging studies confirm or refute this hypothesis? What additional information is needed? What are our conclusions at this point? And how should we now treat the problems that have been identified?

Rationale for Patient Assessment

Health is not concerned merely with the absence of disease, but rather the person's overall mental, physical, and social well-being.[6] Modern healthcare should aim not only to treat acute and chronic disease, but to maximize patients' **health-related quality of life (HRQOL)**. Effective assessment skills are essential to ensure that patient problems are properly identified, prioritized, evaluated, and treated. Health promotion, disease prevention, and management of patients with chronic conditions also require strong assessment skills. Patient assessment is essential for evidence-based practice and care plan development, and patient assessment is required to monitor and evaluate care delivery.

Factors That Affect Health

The factors that affect health include individual genetic makeup, gender, access to medical care and health services, environmental factors (housing, work, school, safe water, clean air), income level, social status, education, social support networks, and personal health-related behaviors (**Table 1-1**).[7] Although genetics, the environment, and access to healthcare play important roles, much of the cost of healthcare in the United States is associated with preventable illness due to personal behaviors. These include smoking, poor eating habits, obesity, lack of physical exercise, and the use of illicit drugs and alcohol. The **social determinants of health (SDOH)** are the "conditions in the places where people live, learn, work, and play . . .": SDOH impact a wide

TABLE 1-1
Factors That Determine Individual Health

- **Genetic makeup**
- **Gender**
  - Men and women tend to have different health problems at different ages
  - Sexual identification can impact health
- **Income level and social status**
  - Socioeconomic status is based on income, education, and occupational status
    - Higher income and social status are associated with better health
    - Poverty and economic instability are linked to poor health
- **Education**
  - Lower education levels are associated with poor health, higher stress, and lower self-confidence
  - Health literacy impacts health
- **Social support**
  - Support from family, friends, and the community are associated with improved health
- **Natural physical environment** (climate, housing, neighborhood, work, school)
  - Climate and air quality
    - Extremes of hot and cold
    - Air pollution
  - Housing factors that may affect health
    - Safe housing
    - Lead exposures
    - Mold, mites, and other allergens
    - Functioning utilities (electricity, sanitation, heating, cooling)
    - Indoor air pollution
    - Residential crowding
  - Neighborhood conditions that may affect health
    - Physical conditions
    - Substandard housing
    - Poor air/water quality, exposure to hazardous substances
    - Crime and safety, safe places to exercise
    - Employment opportunities
    - Access to full-service grocery stores (vs. presence of food deserts)
    - Schools, transportation, and other municipal services
    - Access to medical care
    - Social networks and social support
  - Work environment
    - Safe workplaces
    - Exposure to hazardous materials
    - Level of physical activity
    - Pay, promotions, social support, job satisfaction, stress (those with more control over their working conditions tend to have lower stress)
    - Access to medical care at work
    - Employment status (people who are employed tend to be healthier)
  - School
    - Physical activity and nutrition
    - Environment
    - Access to medical care
  - Environmental stress (work, home, other) impacts other health factors, such as:
    - Alcohol and drug abuse
    - Mental health
    - Eating habits and obesity
    - Blood pressure and immune response
- **Healthcare services**
  - Quality, access, and cost
  - Acute care
  - Preventive care
  - Rehabilitation
  - Chronic disease management
- **Personal behavior**
  - Nutrition
    - Eating habits
    - Availability and consumption of healthy foods
  - Smoking or vaping
  - Drugs and alcohol
  - Activity level
  - Physical exercise
  - Spiritual/religious values (can impact health)

Information from HealthyPeople.gov. Social determinants of health. Available at https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health. Accessed October 31, 2019.; World Health Organization. Health impact assessment. October 23, 2014. Available at https://www.who.int/health-topics/health-impact-assessment#tab=tab_1. Accessed May 18, 2020.; & AAFP. The EveryONE Project. Available at https://www.aafp.org/patient-care/social-determinants-of-health/everyone-project.html. Accessed October 31, 2019.

range of health risks and outcomes.[8] The SDOH include availability of resources to meet daily needs; access to educational, economic, and job opportunities; access to healthcare services; availability of community-based resources; transportation options; public safety; social support; exposure to crime and violence; poverty; segregation; language and literacy; technology; and culture.[9]

Cigarette smoking is the leading cause of preventable death and disease in the United States. Although smoking prevalence among adults has declined significantly from about 42% in 1965 to 20% in 2010 and 14% in 2018, it still accounts for more than 480,000 deaths per year.[10] Cigarette use was highest among those with a GED certificate (36.8%), those with no health insurance or on Medicaid (24.7% and 24.5%, respectively), non-Hispanic American Indian/Alaska Natives (24%), and those with an annual household income <$35,000 (23.2%).[10] Electronic cigarette use (e-cigarette use, aka **vaping**) has increased significantly, especially among younger people. In 2019, an estimated 27.5% of high school students and 10.5% of middle school students reported current use of e-cigarettes, with implications for the development of nicotine dependence in these young people.[11] More recently, there has been an outbreak of serious lung injury, sometimes leading to death, associated with the use of vaping products; e-cigarette or vaping-associated lung injury (EVALI) has been linked with use of products containing THC and vitamin E acetate, although no specific compound or ingredient has been confirmed as the causal agent as of this writing.[12] E-cigarette use has also been associated with increased risk of chronic respiratory disease (e.g., **chronic obstructive pulmonary disease [COPD]**, chronic bronchitis, emphysema, asthma).[13]

RC Insight

Cigarette smoking is the leading cause of preventable death and disease in the U.S. All patients should be asked if they smoke or have ever smoked cigarettes.

The incidence of obesity (body mass index [BMI] ≥30) in adults in the United States for 2015–2016 was 40%, and this is projected to increase to 51% of the population by 2030, with consequences for diabetes, heart disease, hypertension, cancer, osteoarthritis, and life expectancy.[14–16] It is interesting to note that the top five leading causes of death in the United States (**Box 1-1**) in 2017 were heart disease, cancer, accidents, chronic lower respiratory diseases (i.e., COPD), and cerebrovascular disease (stroke), all of which are impacted by personal health-related behaviors.[17]

Environmental factors that may directly affect health include housing, neighborhood of residence, work environment, and access to services near home (see Table 1-1). Factors of special concern with respect to respiratory disease include exposure to air pollution, secondhand smoke, occupational dust and fumes, chemicals, pollen, mold, dust mite and cockroach allergens, animal dander, and other allergens and irritants. A complete patient assessment must include review of social, economic, environmental and personal health-related behaviors that impact patients' health.[18]

BOX 1-1 The 10 Leading Causes of Death in the United States

1. Diseases of the heart (myocardial infarcts or heart failure)
2. Malignant neoplasms (cancer)
3. Accidents (unintentional injuries)
4. Chronic lower respiratory diseases (COPD)
5. Cerebrovascular diseases (including stroke)
6. Alzheimer's disease
7. Diabetes mellitus
8. Influenza and pneumonia
9. Nephritis, nephrotic syndrome, and nephrosis
10. Intentional self-harm (suicide)

COPD, chronic obstructive pulmonary disease.
From Heron M. Deaths: leading causes for 2017. Natl Vital Stat Rep 2019;68(6):1–77.

Triple Aim

The **triple aim** framework for healthcare was developed by the Institute for Healthcare Improvement (IHI) in 2007. The goal of the triple aim framework is to simultaneously improve the patient experience of care, improve the health of populations, and reduce the per capita cost of healthcare.[19] Measures of the patient experience of care include the use of patient surveys as well as measures associated with the delivery of safe, effective, timely, efficient, equitable, and patient-centered care. Measures of population health include health outcomes such as mortality, health and functional status, and healthy life expectancy; measures of disease burden (e.g., incidence and/or prevalence of major chronic conditions); and measures of total healthcare cost per member of the population per month; and hospital and ED utilization rate and/or cost.[19]

More recently, some have added a fourth aim: attaining joy at work, although IHI has suggested that the focus should remain on patients. For others, pursuing health equity has become a fourth aim.[20]

Cost, Access, and Quality

Ultimately, the three main drivers of the healthcare system and, in turn, patient care are *cost, access*, and *quality*. Because these drivers of the healthcare system are so important, we will discuss each separately.

Cost

In 2018, the United States spent $3.6 trillion, or about 18% of its gross domestic product (GDP), on healthcare, and this amount is expected to increase to $5.96 trillion by 2027.[21] The United States spends nearly twice as much on healthcare as other high-income countries.[22] However, in spite of these expenditures, the United States does poorly in comparison to other industrialized nations, ranking 43rd in life expectancy and 56th in infant mortality (**Table 1-2**).

It is interesting to note that half of the U.S. population spends little on healthcare, while 5% of the population

TABLE 1-2
Health Outcomes by Country for Life Expectancy and Infant Mortality

Life Expectancy at Birth (years)	Infant Mortality (deaths/1000 live births)
1. Monaco (89.40)	1. Monaco (1.80)
2. Japan (85.30)	2. Japan (2.00)
3. Singapore (85.20)	3. Iceland (2.10)
4. Macau (84.60)	4. Singapore (2.40)
5. San Marino (83.30)	5. Norway (2.50)
6. Iceland (83.10)	6. Finland (2.50)
7. Hong Kong (83.00)	7. Bermuda (2.50)
8. Andorra (82.90)	8. Sweden (2.60)
9. Guernsey (82.60)	9. Czechia (2.60)
10. Switzerland (82.60)	10. Hong Kong (2.70)
11. Korea, South (82.50)	11. Korea, South (3.00)
12. Israel (82.50)	12. Macau (3.10)
13. Luxembourg (82.30)	13. France (3.20)
14. Australia (82.30)	14. Spain (3.30)
15. Italy (82.30)	15. Anguilla (3.30)
16. Sweden (82.10)	16. Italy (3.30)
17. France (81.90)	17. Luxembourg (3.40)
18. Norway (81.90)	18. Austria (3.40)
19. Liechtenstein (81.90)	19. Belgium (3.40)
20. Jersey (81.90)	20. Guernsey (3.40)
21. Canada (81.90)	21. Germany (3.40)
22. Spain (81.80)	22. Israel (3.40)
23. Austria (81.60)	23. Malta (3.50)
24. Anguilla (81.50)	24. Switzerland (3.60)
25. Netherlands (81.40)	25. Netherlands (3.60)
26. Bermuda (81.40)	26. Belarus (3.60)
27. New Zealand (81.30)	27. Andorra (3.60)
28. Cayman Islands (81.30)	28. Ireland (3.60)
29. Isle of Man (81.30)	29. Lithuania (3.80)
30. Belgium (81.10)	30. Estonia (3.80)
31. Finland (81.00)	31. Jersey (3.80)
32. Puerto Rico (80.90)	32. Slovenia (3.90)
33. Ireland (80.90)	33. Isle of Man (4.00)
34. Germany (80.80)	34. European Union (4.00)
35. United Kingdom (80.80)	35. Denmark (4.00)
36. Greece (80.70)	36. Liechtenstein (4.20)
37. Saint Pierre and Miquelon (80.60)	37. Portugal (4.30)
38. Faroe Islands (80.50)	38. San Marino (4.30)
39. Malta (80.50)	39. Taiwan (4.30)
40. Taiwan (80.20)	40. Wallis and Futuna (4.30)
41. European Union (80.20)	41. United Kingdom (4.30)
42. Turks and Caicos Islands (80.00)	42. Australia (4.30)
43. **United States (80.00)**	43. New Zealand (4.40)
44. Wallis and Futuna (79.80)	44. Poland (4.40)
45. Saint Helena, Ascension, and Tristan da Cunha (79.60)	45. Cuba (4.40)
46. Gibraltar (79.60)	46. Canada (4.50)
47. Denmark (79.50)	47. Greece (4.60)
48. Portugal (79.40)	48. French Polynesia (4.60)
49. Virgin Islands (79.40)	49. Hungary (4.90)
50. Bahrain (79.00)	50. Slovakia (5.10)
51. Chile (78.90)	51. Latvia (5.20)
52. Qatar (78.90)	52. New Caledonia (5.20)
53. British Virgin Islands (78.80)	53. Faroe Islands (5.40)
54. Cyprus (78.80)	54. Bosnia and Herzegovina (5.50)
55. Panama (78.80)	55. Serbia (5.80)
56. Czechia (78.80)	56. **United States (5.80)**

Data from Central Intelligence Agency. The world factbook. 2019 (2017 estimate). Available at https://www.cia.gov/library/publications/the-world-factbook. Accessed May 9, 2019.

accounts for half of all health spending; 90% of heathcare spending is for people with chronic diseases and mental health conditions.[23,24] Ten conditions accounted for 68% of the total healthcare costs in 2016. In order of total cost beginning with the highest, these were ill-defined conditions; circulatory disorders (e.g., stroke, myocardial infarction [MI]); musculoskeletal and connective tissue disease; diseases of the nervous system and sense organs; respiratory disease; endocrine, nutritional, metabolic, and immunity disorders; neoplasms (cancer); injury and poisoning; infectious and parasitic disease; and digestive system disease.[25] The U.S. population is aging, and older patients are responsible for higher healthcare costs. The elderly (age ≥65) made up around 15% of the U.S. population in 2016, but they accounted for 36% of personal healthcare expenses.[26] By 2060, one in four Americans (25%) will be older than 65 years of age.[7] Over half of older adults in the United States have at least one chronic disease, while 77% have two or more chronic conditions; patients with chronic conditions account for 75% of healthcare spending.[27] Chronic cardiopulmonary conditions include **asthma**, **emphysema**, **chronic bronchitis**, chronic obstructive pulmonary disease (COPD), combined asthma/COPD, bronchiectasis, cystic fibrosis, interstitial lung disease, chronic hypertension, coronary artery disease (CAD), and congestive heart failure (CHF). Over 25 million people were diagnosed with asthma in the United States in 2017, and approximately 16 million adults were diagnosed with COPD, while many millions more may have undiagnosed COPD.[28,29] COPD is currently the 4th leading cause of death in the United States, and the actual number of COPD patients is probably closer to 28 million due to underdiagnosis.[17,30,31]

Inpatient hospital costs represent the largest portion of healthcare expenditures in the United States and averaged over $2,400 per patient day in 2017.[32] In 2013, inpatient cost for coronary artery bypass surgery to treat narrowed or obstructed arteries was over $51,400 per patient in the United States, and a single hospital stay for **pneumonia** cost, on average, about $9,500 in 2013.[33–35] A great deal of respiratory care is provided in the hospital setting, often in the intensive care unit (ICU). In one study, ICU total costs per patient in 2015 ranged from a median of $6,624 to $10,382, depending on the type and level of the ICU; median length of ICU stay ranged from 4 to 5 days.[34] Others have estimated ICU costs as high as $32,000 for patients requiring mechanical ventilation and about $13,000 for those not requiring mechanical ventilation.[34] Interventions that reduce ICU length of stay and/or duration of mechanical ventilation could lead to substantial reductions in total inpatient costs.[36]

In terms of total hospital costs, the most expensive conditions include acute MI, congestive heart failure (CHF), pneumonia, acute cerebral vascular disease (e.g., stroke), and respiratory failure.[33]

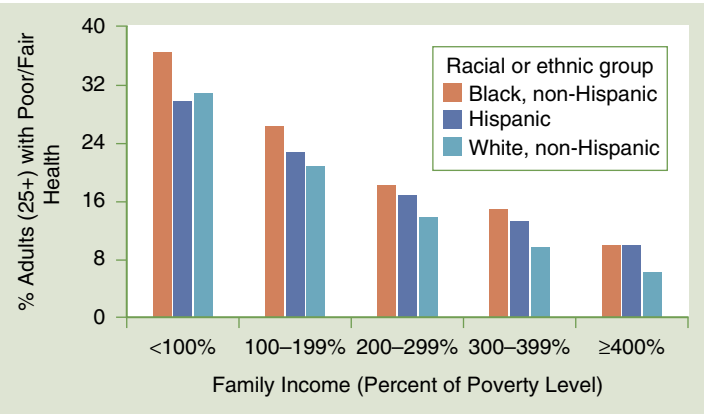

FIGURE 1-1 Racial and ethnic disparities at every income level.
Reproduced from National Health Interview Survey (NHIS) 2001–2005. Age adjusted. Centers for Disease Control and Prevention.

Access

All of us want the best care possible for our patients. Unfortunately, not everyone has access to high-quality healthcare, and many people have little or no access to basic or preventive care. **Healthcare disparities** are of concern for patients with respiratory conditions. For example, African American men have the highest death rate and shortest survival of any racial or ethnic group in the United States for most cancers, including lung cancer.[37,38]

The Agency for Healthcare Research and Quality (AHRQ) describes differences in health outcomes based on race/ethnicity and socioeconomic status, as well as insurance status, sex, sexual orientation, health literacy, and language.[39] Cardiopulmonary disease states or conditions that AHRQ has targeted as priorities for reduction in healthcare disparities include asthma, cystic fibrosis, CHF, CAD (ischemic heart disease, myocardial infarction), and hypertension. Healthy People 2020 has included goals for asthma, COPD, lung cancer, pneumonia, tuberculosis, occupational lung disease, smoking, and sleep disorders.[39–41]

Where you live can have a significant influence on how long you may live. For example, life expectancy can vary within a single metropolitan area dramatically by census tract, zip code, or even block.[42] **Figure 1-1** compares adult health status to family income as a percent of the poverty level.

Figure 1-2 presents a conceptual framework for addressing healthcare disparities. It is thought that by improving economic and social opportunities, living and working conditions, medical care, and personal behaviors, healthcare disparities will be reduced, leading to improved population health.

Quality

It is clear that high healthcare expenditures may not result in better **patient outcomes**. Although the United

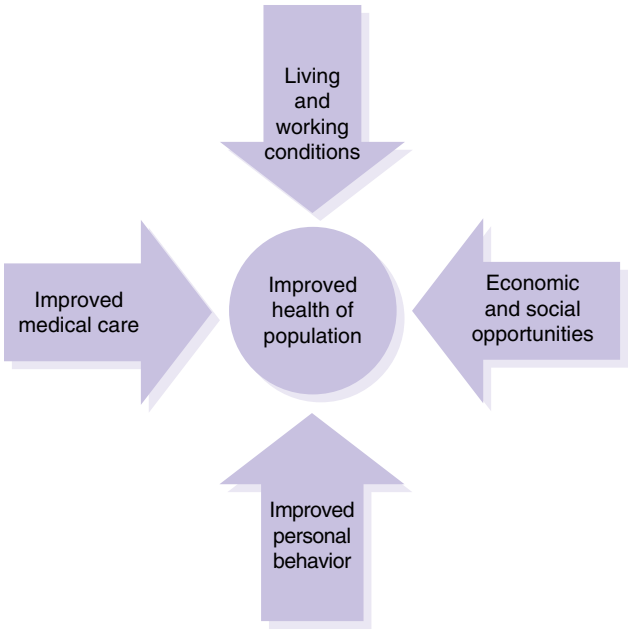

FIGURE 1-2 Conceptual framework for addressing healthcare disparities.

States spends more on healthcare than any other industrialized country, measures of health and mortality are worse.[43] In addition, studies point to major differences in healthcare expenses by geographic area within the United States, with no important differences in patient outcomes. One study found that patients in the higher spending areas received 60% more care and that the increased care could not be attributed to levels of illness or socioeconomic status.[44] A major factor associated with increased cost was higher concentration of medical specialists in high-cost regions.[44]

In the presence of finite resources, should every patient receive all the care he or she prefers to receive, regardless of circumstances? This question gives rise to a number of ethical, moral, and practical dilemmas regarding the cost, quality, and accessibility of care. However, the need for strong assessment skills to help ensure that patients receive appropriate care in a cost-effective and efficient manner is evident.

Misallocation of Respiratory Care

It has been estimated that about 25% of all Medicare expenditures can be attributed to unnecessary variations in care.[44,45] Only 55% of adults receive recommended levels of general preventive care, and adults with a chronic illness receive only 56% of the care recommended by clinical practice guidelines.[46] **Misallocation** of care increases costs and may result in less than optimal health outcomes.

Respiratory care is not immune to misallocation. In a study of respiratory care in the acute care setting, we found that 25% of ordered basic respiratory care procedures were not indicated. In addition, as much as 32% of ordered aerosolized medications were not indicated, whereas about 12% of the patients assessed were not receiving respiratory care that was indicated.[47] Others have estimated that the frequency of unnecessary respiratory care ranges from 20% to 60%.[47]

There are many reasons for the misallocation of care. Fear of lawsuits is sometimes suggested; however, it is likely that some care is provided simply because healthcare professionals believe it might help, probably won't hurt, and, as such, is low-risk. Medical students and physicians-in-training generally learn little about respiratory care, and much of what doctors learn about how to care for respiratory patients is not evidence based.

Optimizing Patient Outcomes

In order to ensure that patients receive appropriate, cost-effective care, the respiratory clinician must be able to correctly identify and treat the patient's problem. Patient education, follow-up care, and rehabilitation, if needed, should be provided. Patients should be provided information regarding health promotion and disease prevention, in addition to smoking cessation interventions for smokers.

All of this requires excellent patient assessment skills to ensure that patients receive the right care at the right time and that unnecessary care is reduced or eliminated. Careful assessment of the patient's history, physical, and laboratory and imaging studies is required. The assessment is then followed by the development, implementation, and monitoring of an evidence-based respiratory care plan. The development and implementation of respiratory care plans using evidence-based clinical practice guidelines can reduce unnecessary care, optimize care delivered, and may reduce costs and improve outcomes.[48] Chapter 2 describes the development, implementation, and evaluation of the respiratory care plan.

Evidence-Based Practice

Evidence-based practice (EBP) integrates research findings with clinical expertise and patient values to provide a structured approach to clinical decision making. By integrating the best available scientific evidence into the decision-making process, EBP has the potential to improve patient outcomes and reduce costs.[45,47–48] EBP can help tell us if a diagnostic test is accurate, how well the test differentiates between patients with and without a specific disease, and whether the test is appropriate to specific situations. EBP can be useful in predicting a patient's prognosis and is the preferred method for selecting treatment.

Sources of Evidence

EBP requires valid, research-based information about the causes, diagnosis, treatment, prognosis, and prevention of specific conditions. Clinical decisions should

not be based solely on preferences or practice patterns. Textbooks may be out-of-date, inaccurate, or based on opinion rather than scientific evidence. EBP requires familiarity with the best evidence and knowledge of how to find it. Sources for EBP include published research reports in peer-reviewed journals, evidence-based systematic reviews (e.g., Cochrane systematic reviews), expert panel recommendations, clinical practice guidelines, and evidence-based electronic clinical decision support resources (e.g., UpToDate®). In order to become proficient at EBP, one must become familiar with various Internet-based tools, such as PubMed, Medline, Google Scholar, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL). Evidence-Based Medical Reviews (EBMR), and the Cochrane Library provide additional evidence-based services (**Box 1-2**).

Types of Evidence

The best single source of evidence is the multicenter **randomized controlled trial (RCT)** in which a clear clinical benefit is demonstrated that outweighs the potential risks of the therapy or procedure. Multiple independent RCTs are sometimes combined using a statistical method called **meta-analysis**, and the resulting meta-analyses can provide strong evidence of the value of a particular treatment or technique. In the absence of multicenter RCTs or multiple independent RCTs, evidence from a single-center RCT may be used with caution. Other types of evidence, from best to least preferable, include results from nonrandomized, concurrent **cohort studies**, historic cohort studies, **case-control studies**, case series, case reports, editorials, and animal studies. The best-evidence pyramid is shown in **Figure 1-3**.

Grades of Recommendations for Therapy

In order to perform EBP, the practitioner begins with a series of questions related to diagnosis, treatment, prevention, or prognosis, which are outlined in **Box 1-3**. These questions are designed to help clarify the patient problem and the intervention or treatment being considered. Next, the treatment or comparison options (if any) and the outcomes sought are identified. Once the EPB questions have been answered, an EBP literature search is conducted, using search terms related to the problem, treatment (or technique), comparison, and desired outcomes. The literature search is normally conducted using an electronic database such as Medline or PubMed. The publications located are then evaluated, and the best available evidence is used to guide clinical decisions.

As we have noted, the strongest evidence sources are well-designed RCTs (sometimes combined via meta-analysis) in which the benefits are clear and outweigh the risks. Factors in evaluating the evidence include the study design, size of the treatment effect, patient selection and type of sample, and important outcomes. RCTs that have unclear or inconsistent results or flaws in methodology can sometimes still provide evidence of moderate quality. Other types of studies (e.g., cohort and case control designs, case series), as well as

BOX 1-2 Online Resources for Evidence-Based Practice

- *PubMed.* PubMed is a comprehensive online database of peer-reviewed biomedical research papers, reviews, and journal articles (www.pubmed.ncbi.nlm.nih.gov).
- *Medline.* Similar to PubMed, Medline is a comprehensive online database of peer-reviewed biomedical research papers, reviews, and journal articles. It is available through college and university library services via OVIDSP.
- *CINAHL (Cumulative Index to Nursing and Allied Health Literature).* CINAHL is a comprehensive online database of nursing and allied health journal publications. It may include articles not listed in other databases. CINAHL is available through college and university library services via EBSCO Publishing (www.ebscohost.com/nursing/products/cinahl-databases/cinahl-complete).
- *Google Scholar.* Google Scholar provides an effective search engine which includes an "Advanced Scholar Search" option. When used properly, recall and precision of Google Scholar is similar to PubMed (http://scholar.google.com).
- *Cochrane Database of Systematic Reviews.* The Cochrane Collaboration (www.cochrane.org) and the Cochrane Library (www.thecochranelibrary.com) provide systematic reviews of the literature for use in evidence-based practice.
- *UpToDate.* This comprehensive medical information service for evidence-based practice is available through college and university library subscription services (www.uptodate.com).
- *Centers for Disease Control and Prevention (CDC).* The CDC offers a wealth of tools and resources on its website (www.cdc.gov).
- *National Institutes of Health (NIH).* The NIH is a valuable source of information on evidence-based medicine (www.nih.gov).

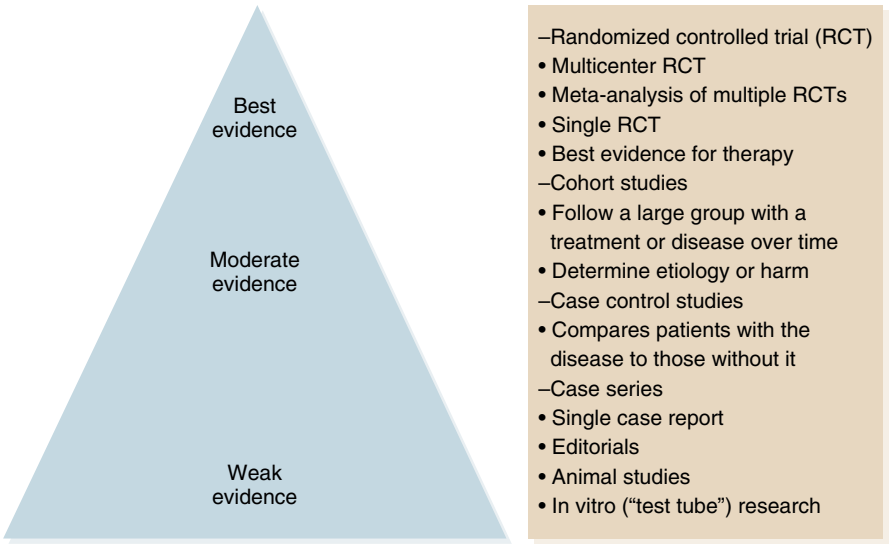

FIGURE 1-3 Evaluating the evidence (critical appraisal) → best evidence pyramid.

BOX 1-3 Use of Questions in Evidence-Based Practice

1. Patient problem or population

- *What patient or problem is being considered?*
  - What is the patient's chief complaint or primary problem? Respiratory examples may include a patient's symptoms or primary disease state or condition:
    - Symptoms: Cough, sputum production, shortness of breath, wheezing, chest tightness, chest pain, other?
    - Disease states or conditions: Asthma "attack," COPD exacerbation, acute respiratory failure, chest trauma, other?
  - What is the larger patient population under consideration?
    - Asthma, COPD, pneumonia, acute lung injury, respiratory failure, acute respiratory distress syndrome (ARDS), congestive heart failure (CHF), other?

2. Intervention

- *What diagnostic method, treatment, medication, procedure, or other intervention is being considered?*
  - The intervention is what you plan to do for the patient. Examples might include:
    - Diagnostic procedures (blood gases, pulmonary function testing, laboratory studies, imaging studies, other)
    - Drugs or medications (antimicrobial agents, bronchodilators, anti-inflammatory agents, cardiac drugs, other)
    - Respiratory care procedures (oxygen therapy, directed cough, lung-expansion therapy, bronchial hygiene techniques, other)
    - Mechanical ventilatory support (invasive or noninvasive)

3. Comparison

- *What alternative treatments or interventions are being considered?*
  - Examples of comparisons for respiratory care might include:
    - Pulmonary rehabilitation versus home care in COPD
    - Peak flow versus symptom monitoring in moderate to severe asthma
    - Volume-control versus pressure-controlled modes of mechanical ventilation in ARDS
    - Rapid drug-susceptibility tests versus conventional culture-based methods for detection of multidrug-resistant tuberculosis
  - A new treatment or procedure may be compared to usual care.
  - In some cases, there may not be an alternative treatment or therapy under consideration.

(*Continues*)

BOX 1-3 Use of Questions in Evidence-Based Practice (*Continued*)

4. Outcome
- *What outcomes are sought?*
  - Diagnosing a condition
  - Relieving or eliminating specific symptoms
  - Stopping or reversing a pathologic process
  - Improving or maintaining function
  - Prevention

5. Searching the literature
- *The next step is to define the search terms and perform a literature review:*
  - Search terms should include the problem, intervention, and comparison (if there is to be a comparison).
  - Examples might include:
    - Noninvasive ventilation and COPD
    - Drug treatment and ARDS
    - Medications and acute asthma exacerbation
    - Antibiotics and ventilator-acquired pneumonia
    - Weaning method(s) and mechanical ventilation in ARDS patients
  - The examples of preferred sources for the literature search are:
    - Medline
    - PubMed
    - Established clinical practice guidelines and expert panel reviews
    - Google Scholar

6. Evaluating the evidence (critical appraisal)
- Following the literature search, the respiratory clinician must evaluate the evidence located. The best evidence sources are well-designed, multicenter RCTs or multiple independent RCTs (sometimes combined via meta-analysis) in which the benefits are clear and outweigh the risks. Factors in evaluating the evidence include the study design, size of the treatment effect, patient selection and type of sample, importance of the outcomes, cost, and patient values and preferences. RCTs that have unclear or inconsistent results or flaws in methodology can sometimes still provide evidence of moderate quality. Other types of studies (cohort and case-control designs, case series), as well as expert-panel recommendations, can also help guide clinical decision making.

7. Applying the evidence to patient care
- The clinician must make decisions regarding diagnosis, treatment, prevention, and/or prognosis based on the evidence. Clinical decisions should balance potential benefit and harm, cost, and patient preferences and values.

COPD, chronic obstructive pulmonary disease; RCT, randomized controlled trial.

expert panel recommendations and systematic reviews, can also help guide clinical decision making. **Table 1-3** provides one method for rating evidence for grades of recommendations for therapy.

Following review of the evidence, the clinician must make decisions regarding diagnosis, treatment, prevention, and/or prognosis. Clinical decisions should balance potential benefit and harm, costs, and patient preferences and values.

Critical Diagnostic Thinking in Respiratory Care

Critical-thinking skills needed by respiratory clinicians include the ability to interpret, analyze, and evaluate data; make clinical inferences; and provide explanations.[49] Respiratory clinicians need to be able to prioritize, anticipate, troubleshoot, communicate, negotiate, make decisions, and reflect on experiences.[49] **Critical thinking** is used in establishing the patient's diagnosis and requires the integration of many different pieces of assessment information derived from the medical record, patient history, physical examination, laboratory tests, and imaging studies and from familiarity with the presentation of various disease states and conditions.[50]

Approach to Hypothesis Formulation and Evaluation

Critical thinking to establish the patient's diagnosis should include the key elements of the scientific method. These key elements or steps are as follows:

1. Identify the problem.
2. Gather additional information to clarify the problem.
3. Formulate possible explanations (hypothesis formulation).
4. Test possible explanations (hypothesis testing).
5. Formulate and implement solutions.
6. Monitor and reevaluate.

TABLE 1-3
Rating the Evidence for Recommendations of Therapy

A number of rating systems have been developed to assess the strength of the evidence for evidence-based practice. The following system evaluates the strength of the recommendation and the quality of the evidence:

Strength of the Recommendation		
Level	**Strength**	**Description**
1	Stronger	Benefits clearly outweigh the risks and burdens (or vice versa) for nearly all patients.
2	Weaker	Risks and benefits are more closely balanced or are more uncertain.
Quality of the Evidence		
Grade	**Quality**	**Description**
A	High	Well-performed randomized controlled trials or overwhelming evidence of some other sort. Further research is very unlikely to change our confidence in the estimate of the effect.
B	Moderate	Randomized controlled trials that are less consistent, have flaws, or are indirect in some way to the issue being graded, or very strong evidence of some other sort. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
C	Low	Low observational evidence (from observational studies, case series, or clinical experience), or evidence from controlled trials with serious flaws. Further research is likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
D	Very low	Any estimate of effect is uncertain.

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Identify the Problem

The first step in making a diagnosis is to identify the patient's problem or chief complaint. The classic question, "Why are you here?" is often a good way to identify the problem from the patient's perspective. For respiratory patients, common complaints include acute or chronic cough, sputum production, shortness of breath (acute or chronic), wheezing, whistling, chest tightness, chest pain, tightness or discomfort, and hemoptysis (expectorating blood-tinged or bloody sputum). Hoarseness, fever, and night sweats are also not uncommon. The time course of symptoms—acute (hours to days), subacute (days to a couple of weeks), or chronic (several weeks to months)—is often helpful in establishing a diagnosis. **Clinical Focus 1-1** lists common problems seen in respiratory care patients.

Gather Additional Information to Clarify the Problem

Following a review of the existing medical record, the respiratory clinician should complete a detailed patient history and perform a thorough physical examination to further identify and clarify the patient's problem(s). The existing medical record review should include patient demographics, previous physician's orders, results of previous history and physical examinations, laboratory and/or imaging reports, progress notes, and reports of procedures. The review of existing medical records is described in Chapter 3.

The patient interview should include the history of the present illness, past medical history, family history, current medications, smoking history (including vaping), environmental data, and occupational history. SDOH such as race and ethnicity, income, education, residence location, social connections/isolation, stress, depression, and use of alcohol or illicit drugs may also be reviewed using a specific interview screening tool.[51,52] The patient should be questioned in more detail regarding specific symptoms associated with pulmonary disease to include cough, sputum production, hemoptysis, dyspnea, and chest pain. The taking of a detailed patient history is discussed in Chapter 4.

The physical examination should include assessment of the patient's general appearance; mental state (anxiety, restlessness, distress) and level of consciousness (alert and awake, sleepy, somnolent); vital signs (pulse, respirations, blood pressure, temperature); skin color, mucosa characteristics, and nail beds (cyanosis); perfusion and capillary refill; and presence of pursed-lip breathing. The chest examination should include inspection, palpation, auscultation, and percussion. Inspection of the chest should include respiratory rate, depth, and pattern; retractions, accessory muscle use, or paradoxical motion of the chest and abdomen; anteroposterior (AP) diameter; and presence of deformity.

CLINICAL FOCUS 1-1 Common Respiratory Care–Related History and Physical Findings

Symptoms

- Acute or chronic cough
- Acute or chronic sputum production
- Anxiety, nervousness, excitement, or restlessness
- Blurred vision
- Chest pain (substernal, pleuritic, musculoskeletal), tightness or discomfort
- Dizziness, fainting
- Fever, chills
- Headache
- Hemoptysis (expectorating blood-tinged or bloody sputum)
- Hoarseness, sore throat
- Night sweats
- Palpitations
- Shortness of breath (acute or chronic dyspnea, orthopnea)
- Sinus pain, runny nose, sneezing, postnasal drip
- Sleep disturbances
- Tremors
- Tingling (extremities)
- Weight loss, loss of appetite

Signs

- Abnormal breath sounds (diminished, crackles, gurgles, wheeze, rubs, bronchial breath sounds, stridor, egophony)
- Abnormal mental state (confusion, disorientation, hallucinations, loss of consciousness, lethargy, somnolence, coma)
- Blood pressure (hypertension, hypotension)
- Heart-rate abnormalities (tachycardia, bradycardia)
- Seizures, convulsions
- Skin (pale, cold, clammy, sweating, cyanosis, rash, redness)
- Ventilatory disorders (tachypnea; hyperventilation; slowed, irregular respirations)

Palpation should assess for tracheal deviation, chest expansion, vocal fremitus, chest wall tenderness, and subcutaneous emphysema. Percussion should note resonance, hyperresonance, or dullness. Auscultation should include assessment for normal and adventitious (abnormal) breath sounds, including crackles, gurgles, wheezes, rubs, stridor, and bronchial breath sounds over the periphery.

Knowledge of the patient's problem or chief complaint can help guide the physical examination in order to obtain evidence to support, reject, or revise specific hypotheses as to the cause of the problem. The physical examination may also identify additional problems such as changes in vital signs, increased work of breathing, abnormal breath sounds, or alterations in mental status. The physical examination is described in Chapter 5.

Formulate Possible Explanations (Hypothesis Formulation)

Following identification and clarification of the patient's problem, the next step is formulating possible explanations or hypotheses as to the cause of the problem. Each symptom and sign identified during the history and physical examination is listed, along with more common and less common possible explanations or causes for this sign or symptom. Based on the review of the existing medical records and history and physical examination, a leading, or differential, diagnosis is proposed. **Table 1-4** describes the more common and less common causes of typical respiratory care assessment findings.[23] The possible causes or explanations for each sign or symptom identified by the patient assessment provide the hypotheses that then need to be tested.

Test Possible Explanations (Hypothesis Testing)

Following a review of the patient's problems and the more common and less common causes for each, a primary or leading hypothesis as to the cause of the problem is developed. This hypothesis, also known as the leading or differential diagnosis, is then tested via additional laboratory and imaging studies. These studies may include oximetry, ABG analysis, **pulmonary function testing (PFT)**, sputum analysis, blood tests to include hematology and blood chemistry, other microbiologic studies, skin tests, and various stains, swabs, and molecular medicine techniques. An electrocardiogram (ECG) may be performed to assess cardiac function, and ECG monitoring is often done in the ICU setting. Imaging studies may include a chest radiograph, CT scan, MRI, and/or ultrasound imaging. Diagnostic bronchoscopy and other diagnostic procedures (e.g., thoracentesis, open lung biopsy) may also be required. Sleep studies may be needed to evaluate sleep-disordered breathing, and exercise stress testing may be used to evaluate pulmonary and cardiac disease. Increasingly, POCT allows for rapidly obtaining results of diagnostic testing at the bedside or in the clinic.

TABLE 1-4
Common and Less-Common Causes of Respiratory Care Assessment Findings

Problem	Common Causes	Less-Common Causes
Acute cough (<4 weeks)	Common cold Influenza Inhalation of irritants (dusts, smog, smoke, chemical fumes, cold air) Pneumonia (may be bacterial, viral, fungal) Acute bronchitis (most commonly viral) Other viral upper respiratory tract infection (pharyngitis, rhinitis, sinusitis, laryngotracheobronchitis [croup], serous otitis) Other bacterial infection (pertussis [whooping cough], tracheobronchitis, ear infection, sinusitis, epiglottitis) Asthma exacerbation Acute exacerbation of COPD Congestive heart failure, pulmonary edema Bronchiolitis (respiratory syncytial virus [RSV])	Tumor, neoplasm Pulmonary emboli Aspiration (foreign body, liquid, gastric acid) Laryngitis ACE inhibitor medication Bacterial sinusitis Lung abscess Smoke inhalation Pleural disease, pleural effusion Diaphragm irritation Mediastinal disease Extrabronchial lesions Fungal lung disease Ornithosis Spontaneous pneumothorax Acute chest syndrome (sickle cell anemia)
Chronic cough (subacute cough is 4 to 8 weeks; chronic cough is >8 weeks)	Postnasal drip (upper airway cough syndrome [UACS] which may be due to allergic rhinitis or sinusitis) Asthma Gastroesophageal reflux disease (GERD) Smoking Chronic bronchitis COPD Emphysema Cystic fibrosis Persistent respiratory tract infection (e.g., *Mycoplasma pneumoniae*, *Chlamydia pneumoniae*, *Bordetella pertussis*) Congestive heart failure (CHF) ACE inhibitor medication (up to 15% of patients receiving ACE inhibitors) Bronchiectasis Neoplasms, bronchogenic carcinoma, lung cancer Lung abscess Recurrent aspiration Mycoplasma pneumonia Pulmonary tuberculosis Pulmonary fibrosis	Neurologic or neuromuscular disease associated with swallowing disorders (i.e., dysphagia) and aspiration (e.g., stroke, Parkinson disease, multiple sclerosis [MS], amyotrophic lateral sclerosis [ALS], elderly patients) Chronic pulmonary edema Mitral stenosis Laryngopharyngeal reflux Laryngeal inflammation or tumor Fungal pneumonia External or middle ear disease Nonasthmatic eosinophilic bronchitis Bronchogenic cyst Sarcoidosis Idiopathic pulmonary fibrosis Mediastinal mass Tracheobronchomalacia HIV Tuberculosis Zenker's diverticulum Aortic aneurysm Vagal irritation Pacemaker wires Pleural disease Pericardial, mediastinal, or diaphragm irritation Somatic cough disorder (previously known as psychogenic cough) Habit cough (aka tic cough)
Acute dyspnea	Acute asthma (intermittent dyspnea) COPD exacerbation (chronic bronchitis, emphysema) Tracheobronchitis Pneumonia or other parenchymal inflammation ARDS Heart failure, acute decompensated heart failure (ADHF) Pulmonary edema (acute) Acute pulmonary emboli Myocardial ischemia (coronary artery disease, acute or chronic) Myocardial infarction, acute coronary syndrome (ACS) Cardiac arrhythmias Pneumothorax, pneumomediastinum Hyperventilation (anxiety, metabolic acidosis) Hypoxemia	Pulmonary hypertension Fever Anemia Pericardial tamponade, effusion or restrictive pericarditis Intracardiac shunt Lung cancer Diaphragmatic paralysis Inhalation of noxious fumes or gases Carbon monoxide poisoning Other poisoning (e.g., organophosphates, Paraquat, salicylate poisoning) Near drowning Massive ascites Space-occupying lesions of the thorax

(*Continues*)

TABLE 1-4
Common and Less-Common Causes of Respiratory Care Assessment Findings (*Continued*)

Problem	Common Causes	Less-Common Causes
	Large pleural effusion Upper airway obstruction (stridor, croup, epiglottis, laryngitis, laryngeal edema, foreign body aspiration, angioedema, anaphylaxis, airway trauma) Aspiration (gastric liquid, foreign body) Atelectasis Chest trauma (pulmonary contusions, rib fractures, flail chest) Sepsis Shock/blood loss Acutely increased work of breathing (decreased compliance and/or increased resistance)	Anaphylaxis Botulism Increased intracranial pressure Obliterative bronchiolitis Hyper/hypothyroidism Acute chest syndrome (sickle cell anemia) Other forms of noncardiogenic pulmonary edema (e.g., neurogenic pulmonary edema, high altitude pulmonary edema [HAPE], flash pulmonary edema) Pulmonary hemorrhage (e.g., malignancy, tuberculosis)
Chronic dyspnea (intermittent or persistent)	Asthma COPD (chronic bronchitis, emphysema, cystic fibrosis) Interstitial lung disease Myocardial dysfunction (heart failure) Obesity/deconditioning Hypoxemia Pulmonary arterial hypertension Neuromuscular disease Bronchiectasis Anemia Ascites Metabolic acidosis Chronically increased work of breathing (decreased compliance and/or increased resistance)	Pulmonary alveolar proteinosis Alveolar microlithiasis Lipoid pneumonia (e.g., aspiration of mineral oil) Lung resection Recurrent pulmonary emboli Lung cancer Persistent large pleural effusion Pleural tumor Kyphoscoliosis, chest wall deformities Tracheal stenosis Tracheomalacia Abdominal mass Pregnancy Congenital heart disease Abnormal hemoglobin Thyroid disease Idiopathic pulmonary hemosiderosis (IPH) Aortic or mitral valve stenosis or regurgitation
Acute sputum production	Viral infection (tracheobronchitis, bronchiolitis, pneumonia) Bacterial infection (tracheobronchitis, pneumonia) Mycoplasma pneumonia Lung abscess Asthma Inhalation of irritants (smoke, smog, dusts, fumes)	Tuberculosis Lung abscess Neoplasms, lung tumor Foreign body aspiration
Chronic sputum production	COPD (chronic bronchitis, cystic fibrosis) Cigarette smoking Asthma Chronic sinusitis with drainage	Bronchiectasis Tuberculosis Lung abscess Bronchopleural fistula with empyema Recurrent aspiration
Hemoptysis	Bronchitis (acute and chronic) Bronchiectasis Lung abscess Tuberculosis Pneumonia (includes necrotizing pneumonias) Neoplasms, bronchogenic carcinoma Pulmonary embolism, pulmonary infarction Cystic fibrosis Congestive heart failure	Trauma Fungal lung disease (includes allergic bronchopulmonary aspergillosis) Empyema Aspiration (foreign body) Inhalation of toxic gases Cocaine-induced pulmonary hemorrhage Arteriovenous fistula Broncholithiasis Goodpasture syndrome Idiopathic pulmonary hemosiderosis Mycetoma Parasitic infection Wegener granulomatosis

Problem	Common Causes	Less-Common Causes
		Bronchogenic cyst Dieulafoy lesion Pulmonary endometriosis (catamenial hemoptysis) Anticoagulation Percutaneous or transbronchial biopsy Bevacizumab treatment Nitrogen dioxide exposure Pulmonary artery perforation following Swan-Ganz catheterization
Pleuritic or chest wall pain	Pleuritis (viral/collagen vascular disease) Pneumonia Pulmonary embolism Empyema Tuberculosis Trauma Rib fracture Pneumothorax Hemothorax	Pulmonary infarction Irritation of intercostal nerves (herpes zoster, spinal nerve root disease) Costochondritis Irritation of the diaphragm Pericarditis, myocarditis
Visceral chest pain	Tumor, neoplasm of major bronchi, mediastinum Abnormalities of the heart, aorta, pericardium Esophageal pain (reflux, tumor), esophagitis	Peptic ulcer disease Cocaine use Cholecystitis
Substernal pain or retrosternal pain	Myocardial ischemia, angina; myocardial infarction; ACS Esophagitis, esophageal pain Arrhythmias Myocarditis Pericarditis GERD	Dissecting aortic aneurysm Congenital cardiovascular anomalies Aortic stenosis Mitral regurgitation Mitral valve prolapse Psychogenic chest pain Stress cardiomyopathy Esophageal rupture

COPD, chronic obstructive pulmonary disease; ACD, angiotensin-converting enzyme; HIV, human immunodeficiency virus.
Information from 50, 53–55.

Chapters 6 and 7 will discuss assessment of oxygenation and ventilation. Chapter 8 will describe ABG analysis and acid–base balance. Chapter 9 will describe laboratory studies, including hematology, clinical chemistry, microbiology, sputum examination, urine analysis, skin testing, histology and cytology, and molecular diagnostics. Chapter 10 will discuss the ECG. Chapter 11 will review imaging studies. Chapter 12 will review pulmonary function testing. Chapter 13 will review diagnostic bronchoscopy, thoracentesis, and open lung biopsy. Chapter 14 will describe acute and critical care monitoring and assessment. Chapter 15 will review sleep studies.

It is important to consider all available information from the patient history, physical examination, and laboratory and imaging studies before coming to a final conclusion about the patient's problem or diagnosis. Review of the available medical records can be enormously helpful, and additional laboratory and imaging studies should be limited to those needed to refine the diagnosis and optimize the patient's care. Confirmation or rejection of the primary hypothesis is then dependent on the results of additional diagnostic tests and laboratory studies.

Formulate and Implement Solutions

Based on the findings from the patient history, physical, laboratory and imaging studies, and medical records, the patient's diagnosis is confirmed, and the respiratory care plan is designed and implemented. The respiratory care plan may include oxygen and/or humidity therapy, aerosol medication administration, lung expansion therapy, chest physiotherapy, and other airway clearance techniques (ACTs) for secretion management, airway care, and/or mechanical ventilatory support. Medical treatment may include administration of anti-infective agents, anti-inflammatory agents, diuretics, cardiovascular medications, and other pharmacologic agents. Procedures may include physical therapy and rehabilitation techniques such as diet and exercise and, in some cases, surgical interventions. The development and implementation of the respiratory care plan is discussed in Chapter 2.

Monitor and Reevaluate

Following the establishment of the patient's diagnosis and development and implementation of the respiratory care plan, the patient is monitored and reevaluated. The respiratory clinician assesses the patient for improvement (or deterioration) in his or her condition and the possible development of new problems that may require further evaluation and treatment. Significant changes in vital signs are especially important and should always lead to reevaluation.

Response to therapy is an important aspect of patient assessment. For example, reversible bronchospasm, as demonstrated by a reduction in wheezing and improvement in PFT expiratory flow rates (PEFR, FEV_1) following bronchodilator therapy, provides additional evidence for a diagnosis of reversible airways disease (asthma and some patients with COPD). Improvement in oxygenation in hypoxemic patients following administration of low to moderate concentrations of oxygen therapy (24% to 40%) is associated with pulmonary disorders with low lung ventilation to perfusion ratios ($\dot{V}/\dot{Q} < 1$ but > 0). Examples of conditions in which hypoxemia may be caused by low $\dot{V}/\dot{Q}$ include asthma, chronic bronchitis, emphysema, bronchiectasis, cystic fibrosis, and CHF. Conditions that may require high concentrations of oxygen in order to reverse hypoxemia are associated generally with intrapulmonary shunting ($\dot{V}/\dot{Q} = 0$) and include atelectasis, severe pneumonia, and **acute respiratory distress syndrome (ARDS)**. Thus, response to oxygen therapy can help support (or refute) a specific patient diagnosis.

Common mistakes in clinical problem solving include failure to consider possible causes that should be considered, consideration of only exotic or uncommon diseases, failure to consider that two or more problems may coexist, and inadequate information gathering and processing. Sometimes a diagnosis has been assigned to a patient without adequately considering alternative explanations. For example, a known COPD patient may suffer from a MI and come to the ED. By mislabeling the patient as suffering from acute exacerbation of COPD, a potentially catastrophic outcome could result. Any diagnosis should be considered as provisional until confirmed by all of the evidence, including appropriate response to therapy. **Clinical Focus 1-2** provides an example of clinical problem solving.

CLINICAL FOCUS 1-2 Clinical Problem Solving

Identify the Problem

Mr. Smith, a 56-year-old male patient, presents to the ED with complaints of increasing shortness of breath (*dyspnea*), difficulty breathing in the supine (flat) position (*orthopnea*), and a history of *chronic cough* with *increasing sputum production*.

Gather Additional Information to Clarify the Problem

Upon *interview,* Mr. Smith indicates he has had a recent change in the color, consistency, and volume of sputum production and worsening ability to perform **activities of daily living (ADLs)** due to increasing shortness of breath. Mr. Smith has an extensive smoking history (two packs per day for 20 years, or 40 pack-years) as well as chronic cough with over a tablespoon per day of generally clear sputum produced. The cough with sputum production has been present most days for over 2 consecutive years. Sputum production has increased over the last several days and is now purulent (containing pus). Current medications include use of an albuterol (bronchodilator) inhaler at home.

On *physical examination*, Mr. Smith has an increased AP diameter of the chest, accessory muscle use on inspiration, and diminished breath sounds with a prolonged expiratory phase, along with crackles and bronchial breath sounds. Vital signs include an increased heart rate (pulse = 115, tachycardia), increased respiratory rate (f = 26, tachypnea), and elevated temperature. Pulse oximetry indicates a reduced arterial oxygen saturation (Spo_2 = 82%) while breathing room air. Together, the symptoms and signs identified on history and physical exam make up the patient's problem list.

Formulate Possible Explanations (Hypothesis Formulation)

Mr. Smith's findings so far can be summarized as follows:

- History findings are associated with a chronic respiratory problem:
  - Chronic cough with sputum production
  - Decreased ability to perform ADLs
  - Smoking history of 40 pack-years
  - Home use of inhaled medications (albuterol inhaler)
- Physical examination findings are associated with acute distress:
  - Tachypnea, accessory muscle use, and tachycardia.

- Increasing dyspnea, orthopnea.
- Diminished breath sounds indicate decreased air movement, and a prolonged expiratory phase is associated with air trapping.
- Crackles upon auscultation are associated with alveolar fluid or, in some cases, fibrosis.
- Bronchial breath sounds heard over the periphery of the chest are associated with consolidation.
- Increased chest diameter is associated with overinflation of the lungs.
- Reduced Spo_2 on room air indicates hypoxemia.

Common causes for these findings include *chronic bronchitis, bronchiectasis,* and *acute exacerbation of COPD*. Acute exacerbation of COPD can be precipitated by increased air pollution, upper respiratory tract infection, flu virus, bacterial infection, or pneumonia.

Test Possible Explanations (Hypothesis Testing)

Mr. Smith presents with increasing dyspnea, tachypnea, tachycardia, reduced Spo_2, accessory muscle use, and chronic cough with recently increased purulent sputum production. These findings, along with a significant smoking history, increased AP chest diameter, abnormal breath sounds, and prolonged expiratory phase suggest that Mr. Smith is likely suffering from an *acute exacerbation of COPD*; however, other acute and chronic pulmonary problems will need to be ruled out (e.g., pneumonia, pulmonary edema, pleural effusion, pneumothorax, pulmonary embolus).

Common causes or triggers for acute exacerbation of COPD include viruses, bacteria, and possibly air pollution or pulmonary embolus. Common cold viruses (e.g., rhinovirus, respiratory syncytial virus [RSV], parainfluenza, adenovirus, human coronavirus), influenza, and bacterial infection have all been associated with COPD exacerbation. Consequently, an upper respiratory tract infection, the common cold or flu, and possible development of pneumonia will need to be considered. Laboratory and imaging studies that should be considered include:

- Pulse oximetry.
- ABG analysis (for suspected acute-on-chronic respiratory failure or evaluation of the need for ventilatory support).
- Complete blood count (CBC) and differential.
- Blood chemistry (serum electrolytes and blood glucose).
- Chest radiograph (CXR) to rule out pneumonia, or other acute pulmonary disease (e.g., pleural effusion, pulmonary edema, pneumothorax). COPD patients may show evidence of lung hyperinflation on CXR (e.g., flat diaphragm, increased radiolucency, increased retrosternal airspace on lateral CXR).

Review of the diagnostic testing results allows us to test our hypothesis that the patient is suffering from an acute exacerbation of COPD. *Pulmonary function testing* should also be performed when the patient has recovered in order to document the presence and severity of COPD.

Formulate and Implement Solutions

Mr. Smith's history, physical examination, and vital signs are consistent with acute exacerbation of COPD. ABGs show chronic ventilatory failure with moderate to severe hypoxemia while breathing room air (pH = 7.35; Pao_2 = 47 torr; $Paco_2$ = 55 torr; Sao_2 = 82%). CBC indicates slightly elevated hemoglobin and an increased white blood cell count. Blood chemistry indicates electrolytes in the normal range, except for potassium, which is slightly reduced. The chest radiograph indicates hyperinflation and what appear to be new infiltrates. *These findings are consistent with acute exacerbation of COPD associated with a superimposed pneumonia.*

Treatment of acute exacerbation of COPD should include *oxygen therapy* and *aerosolized bronchodilators* (β_2-agonists [e.g., albuterol or levalbuterol] and/or anticholinergic agents [e.g., ipratropium bromide]). A short course of systemic *glucocorticoids* (i.e., steroids) may be considered (e.g., oral prednisone, 30–40 mg/day × 5 days) and *antibiotics* in cases of suspected bacterial infection or if hospitalization is necessary.[56,57] Antiviral therapy is recommended for patients in the presence of influenza infection.

Noninvasive ventilation (NIV, aka noninvasive positive pressure ventilation [NPPV]) should be considered in the presence of elevated $Paco_2$ with acidosis and continuing ventilatory distress. If NIV fails, invasive mechanical ventilation may be required in the presence of worsening hypoventilation with acidosis. Potassium replacement may be needed in the presence of low potassium, and diuretics may be given to treat peripheral edema and fluid overload.

Monitor and Reevaluate

The respiratory care plan for Mr. Smith includes oxygen therapy at 2 L/min via nasal cannula to maintain

(*Continues*)

CLINICAL FOCUS 1-2 Clinical Problem Solving (*Continued*)

his Spo_2 in the range of 88% to 92%. Some patients with COPD develop hypercapnia when oxygen is administered, and this may be due to oxygen's effect on $\dot{V}/\dot{Q}$ and dead space ventilation.[58] Caution should be employed to avoid uncontrolled oxygen therapy and oxygen-induced hypercapnia in this patient due to his preexisting chronic CO_2 retention.[59]

Bronchodilator therapy, steroids, and antibiotics are ordered. Mr. Smith should now be monitored for adequate oxygenation, ventilation, and acid–base balance. Once the acute COPD exacerbation/pneumonia has been reversed, a smoking cessation program should begin, and pulmonary function testing completed. Regular treatment with inhaled bronchodilators should be continued to reduce symptoms and risk of future hospitalizations. A long-acting muscarinic antagonist (LAMA, e.g., tiotropium) ***or*** long-acting beta-2 (β_2) agonist ([LABA], e.g., salmeterol or formoterol) along with a short-acting beta-2 (β_2) agonist (SABA) bronchodilator for symptom relief is a reasonable course, considering this patient's risk of future exacerbations.[60] Some patients with asthma/COPD overlap may benefit instead from a combination of a long-acting bronchodilator and an inhaled corticosteroid (ICS).[60] Medications are then adjusted based on symptoms, response to therapy, and risk of exacerbation. Patients with moderate to severe continuing symptoms, along with a high risk of future exacerbations may receive a combination of LAMA and LABA and an ICS. This "triple therapy" refers to the combination of a LAMA, LABA, and ICS, which may be useful to reduce future hospitalizations in certain patients.[60] A formal pulmonary rehabilitation program should also be considered.

ED, emergency department; COPD, chronic obstructive pulmonary disease; AP, anteroposterior; ABG, arterial blood gas; Pao_2, partial pressure of oxygen, arterial; $Paco_2$, arterial partial pressure of carbon dioxide; Sao_2, arterial oxygen saturation; $\dot{V}/\dot{Q}$, ventilation-perfusion.

Typical Presentations of Common Respiratory Disorders

Common respiratory disorders include **restrictive lung disease**, **obstructive lung disease**, and problems of oxygenation and ventilation. Obstructive disorders are associated with a decrease in PFT expiratory flow rates (FEV_1/FVC, FEV_1, $FEV_{25–75\%}$, PEF) and include asthma, chronic bronchitis, emphysema, combined/COPD, bronchiectasis, and cystic fibrosis. Because patients have trouble getting air out of the lungs, the FEV_1/FVC ratio is reduced. Restrictive disorders are associated with a decreased ability to take a deep breath in, as indicated by a reduced inspiratory capacity (IC), vital capacity (VC), and total lung capacity (TLC) as assessed by PFT. Acute restrictive problems include pneumonia, atelectasis, ARDS, pleural effusion, pneumothorax, and pulmonary edema associated with CHF.

Pneumonia is an infection of the lung parenchyma, the area of the lung where gas exchange occurs. Pneumonia can be caused by a number of different pathogens, including bacteria, viruses, and fungi. Common bacterial causes of pneumonia include *Streptococcus pneumoniae, Staphylococcus aureus, Haemophilus influenzae, Pseudomonas aeruginosa, Mycoplasma pneumoniae* (a type of "atypical" bacteria), *Legionella pneumophila, Klebsiella pneumoniae,* and others. Viral pneumonia can be caused by influenza virus, parainfluenza virus, metapneumovirus, RSV, rhinovirus, and adenovirus. A novel coronavirus originating in China (SARS-CoV-2) has recently been associated with development of COVID-19, an acute respiratory disease characterized by the development of cough, fever, dyspnea, bilateral infiltrates on chest imaging, and respiratory failure in some patients. Major complications of COVID-19 include development of pneumonia, severe hypoxemia, respiratory failure, shock, multiorgan failure, and ARDS.

RC Insight

Knowledge of the typical presentations of common respiratory disorders can aid the respiratory care clinician in formulating possible explanations for clinical findings.

Respiratory virus profiles (RVP) obtained by multiplex polymerase chain reaction (PCR) are now routinely available using a nasopharyngeal swab, nasal aspirate, or bronchoalveolar lavage (BAL) sample. Assays can simultaneously detect influenza A, influenza B, RSV A, RSV B, parainfluenza 1, parainfluenza 2, parainfluenza 3, rhinovirus, metapneumovirus, and adenovirus, and results from hospital laboratories can be available in a few hours. COVID-19 is diagnosed based on signs and symptoms, history of exposure or travel to an area with documented community spread, and confirmed via reverse transcription polymerase chain reaction testing (RT-PCR).

Chronic restrictive disorders include pulmonary fibrosis, lung cancer, thoracic deformity, neuromuscular weakness, and obesity. Both restrictive and obstructive disorders can lead to problems with oxygenation and ventilation. Other common respiratory care–related problems often seen in the acute care setting that may affect oxygenation and or ventilation are listed in **Clinical Focus 1-3**. Typical presentations of common respiratory disease states and conditions are described in **Table 1-5**.

CLINICAL FOCUS 1-3 Common Disease States and Conditions Seen in Respiratory Care

Acute Restrictive Disease

- Acute bronchitis
- Acute respiratory distress syndrome (ARDS)*
- Acute respiratory failure
- Atelectasis
- Lung cancer
- Pleural effusion/pleural disease
- Pneumonia
- Pneumothorax
- Pulmonary edema

Chronic Restrictive Disease

- Interstitial lung disease (pulmonary fibrosis/other)
- Lung cancer
- Obesity
- Pneumoconiosis
- Sarcoidosis (restrictive/obstructive)
- Thoracic deformity

Obstructive Disease

- Asthma
- Bronchiectasis
- Chronic bronchitis
- COPD
- Cystic fibrosis
- Emphysema
- Sarcoidosis (restrictive/obstructive)
- Upper airway obstruction

Cardiac and Circulatory Problems

- Abdominal aortic aneurysm
- Abnormal cardiac stress test
- Acute myocardial ischemia
- Aortic valve disease
- Cardiac arrhythmias
- Chronic hypertension
- Chronic, stable angina
- Congenital heart disease
- Congestive heart failure (CHF)
- Coronary artery disease (CAD)
- Heart murmur
- Hyperlipidemia
- Mitral valve prolapse
- Myocardial infarction (MI)
- Peripheral artery disease (claudication)
- Peripheral edema
- Pulmonary vascular disease (pulmonary embolus, pulmonary hypertension)
- Syncope

Other Problems Affecting the Cardiopulmonary System

- Alcohol and/or illicit drug abuse
- Anemia
- Burns and smoke inhalation
- Chest trauma
- Diabetes
- Drug overdose
- Fluid and electrolyte disturbances
- Fungal lung disease
- Hypersensitivity pneumonitis
- Malnutrition
- Neurologic problems affecting ventilatory drive
- Neuromuscular disease affecting respiration
- Obesity
- Postoperative care
- Preoperative care
- Renal failure
- Sepsis
- Shock (cardiogenic, hypovolemic, septic, anaphylactic)
- Sleep-disordered breathing
- Tobacco addiction/dependence
- Trauma
- Upper respiratory tract infection

COPD, chronic obstructive pulmonary disease.

*The Berlin Definition of ARDS incorporates variables and related criteria for mild ARDS that were previously described as acute lung injury (ALI).

TABLE 1-5
Typical Presentation of Common Respiratory Disease States and Conditions

Disease State or Condition	History	Physical Examination	Laboratory Tests
Viral upper respiratory tract infection—commonly due to the common cold or influenza. Colds are often caused by rhinoviruses although coronaviruses, RSV, and other viruses may be the cause.	Cough, rhinitis, nasal congestion, sore throat, malaise, body aches. Nasal discharge may be clear or purulent. Sneezing, sore throat, throat irritation (scratchy throat), headache, facial or ear pressure may be present. Low-grade fever may occur, especially in children.	Nasal mucosal swelling, nasal congestion; mucopurulent nasal discharge; pharyngeal erythema (throat inflammation, redness); fever; pharynx pale, boggy, swollen. Breath sounds may show gurgles or coarse rhonchi.	Chest radiograph not routinely indicated, may be clear; bacterial cultures not routinely indicated; influenza testing (e.g., nasal swab) may be considered, especially during flu season in certain patients; throat culture may rule out streptococcal infection.
Sinusitis	Nasal congestion, nasal obstruction, purulent discharge; facial pain, pressure, or fullness; upper jaw (maxillary) tooth discomfort; headache, fatigue, cough, ear pressure, pain, or discomfort; reduced or absent sense of smell; fever may be present.	Headache pain worsened by touch; redness and edema over cheekbone or around eyes; purulent drainage from nose or throat; diffuse mucosal edema.	Sinus CT scan with contrast or MRI if complications are suspected; cultures by otolaryngologist if serious complications suspected; nasal or swab cultures are not useful.
Mycoplasma bronchitis or pneumonia. *Mycoplasma pneumoniae* is a common bacterial cause of upper respiratory tract infection (URI).	May be asymptomatic, common findings similar to URI, acute bronchitis, and pneumonia. Dry hacking cough progressing to cough with purulent sputum; sore throat, runny nose, nasal inflammation, ear pain; dyspnea, although uncommon, may occur.	Findings similar to URI, acute bronchitis or pneumonia. With pneumonia: low-grade fever, headache, malaise, pleuritic chest pain, chest soreness, and dyspnea may be present. Crackles and wheezing may occur.	For URI and acute bronchitis, laboratory and imaging generally are not needed. For pneumonia, *M pneumoniae* molecular testing (e.g., polymerase chain reaction [PCR], nucleic acid amplification test [NAATs]) may be used (serologic testing provides an alternative to molecular testing). Gram stain and culture may not be helpful. Hemolysis may be present with reduced Hb levels and associated findings; chest radiograph shows signs of atypical or viral pneumonia.
Pneumonia	Cough, fever, dyspnea, pleuritic chest pain, and sputum production. Mucopurulent sputum may be bacterial pneumonia, whereas scant watery sputum may be atypical pneumonia (color may vary with type of infection, for example, rust-colored with pneumococcal pneumonia). Elderly patients: sometimes only confusion, fatigue, with minimal or no pulmonary complaints.	Sudden onset, spiking fever with chills (rigors), mental status changes associated with hypoxemia, tachycardia, tachypnea, cyanosis, crackles, bronchial breath sounds, egophony, vocal fremitus, diminished breath sounds, dull percussion note.	New or progressive infiltrate on chest radiograph is the "gold standard"; CT scan is more sensitive for certain conditions; lung ultrasound can be useful. Gram stain and sputum culture plus urinary antigen testing may yield rapid diagnosis. Leukocytosis (elevated WBC) with left shift; leukopenia (↓WBC) can occur. Blood culture may be helpful for hospitalized patients. Multiplex polymerase chain reaction (PCR) tests can rapidly detect *C pneumoniae*, *M pneumoniae*, and 14 viral pathogens.
Atelectasis	History of recent abdominal or thoracic surgery, immobilization, chest wall pain, history of bronchial obstruction (e.g., mainstem intubation), muscular weakness, thoracic or abdominal limitation to diaphragmatic excursion (ascites, obesity, peritonitis, thoracic deformity, etc.), weakness, neuromuscular disease, pneumonia or other acute restrictive disease, other chronic restrictive pulmonary disease, respiratory depressants (sedatives or narcotics).	Decreased chest wall movement over affected side, absent or diminished breath sounds, dull percussion node, crackles, signs of increased work of breathing, hypoxemia.	Findings associated with atelectasis on chest radiograph (e.g., elevated hemidiaphragm on affected side, increased opacification of the airless lobe, displacement of lung fissures), decreased inspiratory capacity, vital capacity, tests for hypoxemia (Spo_2 and/or ABGs).

Disease State or Condition	History	Physical Examination	Laboratory Tests
Asthma	Wheezing, dyspnea, cough; symptoms may worsen at night. Obtain history of medication use (bronchodilators and anti-inflammatory medications including steroids), aspirin or nonsteroidal anti-inflammatory drugs, ED visits, hospitalizations, ICU admissions, need for intubation and ventilatory support, history of cigarette smoking or vaping. Assess for asthma triggers, and recent exposure.	Assess for signs of respiratory distress (tachypnea, accessory muscle use, cyanosis). Wheezing, rhonchi more prominent on expiration. Assess for allergic disease.	Pulse oximetry, ABGs if ventilatory derangements present, spirometry (bedside spirometry or measurement of peak expiratory flow). Allergy skin testing or measurements related to IgE (e.g., radioallergosorbent test [RAST] may assist in identifying asthma triggers. Chest x-ray is usually normal.
COPD exacerbation (chronic bronchitis, emphysema)	Cough with sputum production (especially in chronic bronchitis), increased dyspnea, orthopnea, decreased mobility, history of previous exacerbations (especially requiring hospitalization, ICU admission, mechanical ventilation), use of bronchodilators and steroids.	Diffuse wheezing, increased respiratory rate, signs of respiratory distress and increased work of breathing, clinical manifestations of hypoxemia, increased AP diameter, accessory muscle use, pursed-lip breathing, diminished breath sounds, prolonged expiration, wheezing, crackles, rhonchi, dependent edema.	Pulse oximetry; chest radiograph to rule out new infiltrates, pneumonia, pneumothorax, pleural effusion; CBC and differential; serum electrolytes and glucose; ABGs if acute chronic ventilatory failure is suspected. Consider ECG and cardiac troponins if tachycardia or myocardial ischemia is suspected; BNP and D-dimer if pulmonary embolus is suspected. Assess PFTs when patient is recovered.
Pleural effusion	Dyspnea, pleuritic chest pain, cough.	Chest wall movement reduced over affected side, dull percussion note, absent or diminished breath sounds over effusion, egophony and/or bronchial breath sounds above effusion, pleural rub may be present.	Chest x-ray consistent with pleural effusion, thoracentesis, pleural fluid analysis (appearance, WBC and differential, Gram stain, culture, glucose, amylase).
Pneumothorax	Chest pain (pleuritic), dyspnea, history of trauma, invasive procedures (e.g., central venous catheterization, thoracentesis), spontaneous pneumothorax, COPD, cystic fibrosis, cancer, pneumonia, or tuberculosis.	Tachycardia, tachypnea, respiratory distress, tracheal deviation to opposite side with tension, decreased chest wall movement on affected side, resonant or hyperresonant percussion note, absent or decreased breath sounds.	Chest x-ray consistent with pneumothorax; oximetry and ABGs may show hypoxemia with or without hypercapnia. Ventilated patients may have increased peak pressures, reduced volume delivery.
COVID-19 (SARS-CoV-2 infection)	History of close contact with infected person (confirmed or suspected) or history of travel to an area with documented community spread, fever, cough, and/or dyspnea, myalgias, possible GI symptoms (nausea, diarrhea), possible loss of senses of smell or taste. Other symptoms may include headache, sore throat, runny nose; some patients may be asymptomatic or have only mild symptoms.	Fever, dry cough, signs of respiratory distress, increased work of breathing, hypoxemia/pneumonia.	Positive COVID-19 RT-PCR test. Mild cases may show no or mild pneumonia on chest imaging. Severe to critical patients: hypoxemia (SpO_2 or ABGs), bilateral infiltrates on chest imaging. Labs may show lymphopenia, elevated aminotransaminase levels, elevated lactate dehydrogenase levels, and elevated inflammatory markers. Serologic tests may identify SARS-CoV-2 antibodies associated with current or previous infection.

RSV, respiratory syncytial virus; CT, computed tomography; WBC, white blood count; Spo_2, arterial blood oxygen saturation; ABG, arterial blood gas; ED, emergency department; ICU, intensive care unit; COPD, chronic obstructive pulmonary disease; AP, anteroposterior; CBC, complete blood count; ECG, electrocardiogram; BNP, brain natriuretic peptide; PFT, pulmonary function test; SARS, severe acute respiratory syndrome; CoV, coronavirus; GI, gastrointestinal; RT-PCR, reverse transcription polymerase chain reaction.

Data from 50, 53, 54, 56, 57, 60–67.

Summary

Respiratory therapists, nurses, and physicians are intimately involved in the diagnosis, treatment, care, and follow-up evaluation of patients with acute and chronic cardiopulmonary disease. Effective assessment skills are required in order to ensure patients receive the right care, at the right time, and unnecessary care is minimized or eliminated. Key areas of respiratory care patient assessment include the history, physical examination, and selection and interpretation of diagnostic testing results. While treatment of disease and associated symptoms are foundational to the practice of respiratory care, the ultimate goal is to maximize patients' health-related quality of life. Factors that affect health include genetic makeup, access to medical care, environmental factors, and personal health-related behaviors. A patient's socioeconomic status, racial and ethnic background, and residential location can have a significant impact on health. The three main drivers of the healthcare system are cost, access, and quality. The overall goal of the healthcare system is to ensure that patients have access to high-quality healthcare while controlling costs.

Providing high-quality, cost-effective care requires evidence-based practice, which integrates research findings, clinical expertise, and patient values. The best sources of evidence, in order of strength, are the multicenter RCT, meta-analyses of multiple RCTs, and single RCTs. Cohort studies, case-control studies, and case-series provide weaker, but sometimes useful evidence. Clinical practice guidelines and evidence-based databases can also be useful.

Critical diagnostic thinking requires that the respiratory care clinician properly identifies the problem, gathers additional information, formulates hypotheses, tests hypotheses, formulates and implements solutions, and monitors and reevaluates care provided. Recognition of common causes of assessment findings, and knowledge of typical presentations of respiratory diseases can allow the respiratory care clinician to properly assess and treat the patient's problems.

Key Points

- Respiratory care is the healthcare discipline that specializes in the promotion of optimum cardiopulmonary function, health, and wellness.
- Respiratory care patient assessment includes the history, physical examination, and diagnostic testing (laboratory tests and imaging studies).
- Patient assessment is needed to ensure that patients' problems are properly identified, prioritized, evaluated, and treated.
- Health may be defined as a person's overall mental, physical, and social well-being.
- The primary factors that determine health are individual genetic makeup; access to medical care; environmental factors (housing, work, school); and personal health-related behaviors, such as smoking, physical exercise, nutrition, and the use of illicit drugs and/or alcohol.
- The top five leading causes of death in the United States are heart disease, cancer, COPD, stroke, and accidents.
- Cigarette smoking is the leading cause of preventable death and disease in the U.S.
- Electronic cigarette use (vaping) has increased significantly, especially among younger people.
- E-cigarette or vaping-associated lung injury (EVALI) is an acute or subacute respiratory illness that has been linked to the use of products containing THC and vitamin E acetate, although a definitive cause has not been identified.
- The triple aim of healthcare is to simultaneously improve the patient experience of care, improve the health of populations, and reduce the per capita cost of healthcare.
- The major drivers of the modern healthcare system are quality, access, and cost.
- Patients with chronic disease, such as asthma, COPD, heart disease, and diabetes, account for about 75% of overall healthcare spending.
- In spite of spending more on healthcare, the United States ranks below many other nations in measures of overall health.
- Careful patient assessment may reduce misallocation of care, decrease costs, and save valuable resources.
- A major goal of patient assessment is to ensure that patients receive the right care at the right time and that unnecessary care is reduced or eliminated.
- Evidence-based practice uses research findings to aid in clinical decision making.
- The best sources of evidence for clinical decision making include the results of well-designed randomized controlled trails, systematic reviews, expert panel recommendations, and national/international clinical practice guidelines and standards.
- Critical thinking to establish a patient's diagnosis includes identifying the problem, gathering additional information, formulating hypotheses, hypothesis testing, formulating and implementing solutions, and monitoring and reevaluating the patient.
- Common respiratory problems include cough, dyspnea, sputum production, hemoptysis, and chest pain.
- Common respiratory disease states or conditions requiring patient assessment include upper respiratory tract infection, pneumonia, atelectasis, asthma, emphysema, COPD, acute or chronic bronchitis, acute respiratory failure, ARDS, pulmonary edema, chest trauma, interstitial lung disease, and lung cancer.
- COVID-19 is an acute respiratory viral infection caused by the novel coronavirus, SARS-CoV-2; COVID-19 disease may be mild, severe, or critical.

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CHAPTER

2

Development and Implementation of Respiratory Care Plans

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CHAPTER OUTLINE

CHAPTER OBJECTIVES

1. Describe the purpose of a respiratory care plan.
2. Identify the key elements of a respiratory care plan.
3. Describe common conditions that may require development of a respiratory care plan.
4. Define *respiratory failure*, and give examples of several types of respiratory failure.
5. Define *ventilatory failure*, and contrast acute ventilatory failure and chronic ventilatory failure.
6. Give examples of appropriate outcome measures for a respiratory care plan.
7. Outline the key steps in the development and implementation of a respiratory care plan.
8. Develop a respiratory care plan to maintain adequate tissue oxygenation.
9. Create a respiratory care plan for the treatment and/or prevention of bronchospasm and mucosal edema.
10. Describe the care of patients with asthma and COPD.
11. Design a respiratory care plan to mobilize secretions.
12. Propose a respiratory care plan for the treatment and/or prevention of atelectasis and pneumonia.
13. Give examples of types of respiratory care plans used in the intensive care unit.
14. Explain the role of diagnostic testing in the development of a respiratory care plan.

KEY TERMS

acute respiratory distress syndrome (ARDS)
acute respiratory failure (ARF)
acute ventilatory failure (AVF)
airway clearance techniques (ACT)
antiasthmatic medication
anti-inflammatory agent
asthma
atelectasis
bronchial hygiene
bronchiectasis
bronchodilator therapy
bronchospasm
chest physiotherapy (CPT)
chronic bronchitis
chronic obstructive pulmonary disease (COPD)
chronic ventilatory failure (CVF)
history
hypoxemia
incentive spirometry (IS)
inhaled corticosteroid (ICS)
intermittent positive pressure breathing (IPPB)
lung expansion therapy
mechanical ventilation
mucosal edema
oxygen therapy
physical
pneumonia
positive airway pressure (PAP)
protocol
pulmonary edema
respiratory care plan
retained secretion
six-minute walk test (6MWT)
SOAP note
treatment menu

Overview

This chapter provides a guide to the development, implementation, and evaluation of respiratory care plans. The respiratory care plan provides a detailed description of the care to be provided based on the individual needs of the patient. Care plans often include assessment, diagnosis, or problem list; goals and/or objectives; specific activities or interventions to be taken; outcomes of care provided; and evaluation. In order to develop an appropriate respiratory care plan, the clinician must first perform a thorough patient assessment, including a review of the patient's existing medical record, a patient interview, and a **physical** assessment. The bedside measurement of clinical parameters related to oxygenation, ventilation, and pulmonary function may be performed. Pulse oximetry (Spo_2) is routinely used to assess oxygenation status. Arterial blood gases should be obtained if there is concern regarding the patient's ventilatory status, acid–base balance, or the reliability of Spo_2 values. Laboratory, imaging, and other diagnostic studies may be needed to further define and clarify the patient's problem and diagnosis. Following establishment and clarification of the patient's diagnosis and/or problem list (see Chapter 1), a respiratory care plan is developed, implemented, and evaluated.

Introduction to Respiratory Care Plans

The **respiratory care plan** provides a written description of the care the patient is to receive. The plan is based on a careful patient interview and physical assessment, review of diagnostic test results, and consideration of the treatment modalities available, sometimes known as the **treatment menu**. The respiratory care plan may take the form of physician's orders, a detailed progress note in the medical record, an established **protocol**, completion of a standardized respiratory care consultation and treatment plan template, or the use of problem-oriented medical records (e.g., SOAP notes). The respiratory care plan can be viewed as an individualized protocol for the patient.

A basic respiratory care plan often includes the following elements:

- Goals of therapy
- Device or procedure to be used or medications to be given
- Method or appliance to be used
- Gas source or oxygen concentration
- Device pressure, volume, and/or flow
- Frequency of administration and duration of therapy

SOAP notes are sometimes used to document patient care plans:

S (Subjective). Refers to what the patient says, or subjective information obtained from the chart or medical record.
O (Objective). Refers to what the clinician observes or objective test results.
A (Assessment). Refers to the clinician's assessment.
P (Plan). Refers to the plan of care.

A modification known as SOAPIER adds care plan documentation of the following:

I (Intervention). What was done.
E (Evaluation). The clinician's evaluation of the care provided.
R (Revision). Any changes in care provided based on the clinician's evaluation.

Further details of SOAPIER can be found in Chapter 3. The respiratory care plan may also include a statement of how the intensity and/or duration of therapy will be adjusted and when the therapy will be discontinued. Assessment of the outcomes of therapy may also be included, as well as measurable objectives of the care delivered.

RC Insight

The respiratory care plan provides a written description of the care the patient is to receive, based on a thorough assessment and determination of the care needed.

In summary, the respiratory care plan provides the written plan of treatment that the patient will receive. The plan may include goals, objectives, rationale, significance, and a description of how care will be assessed. Following a careful patient assessment, the respiratory care plan is developed, implemented, and evaluated. A summary of the types of care often included in the respiratory care plan is provided in **Table 2-1**.

Common Conditions Requiring Respiratory Care Plan Development

Problems that affect oxygenation and/or ventilation often require the development of a respiratory care plan. Other common respiratory problems include **bronchospasm** and **mucosal edema**, **retained secretions**, airway plugging, infection, consolidation, inadequate lung expansion, **atelectasis**, and **pulmonary edema**. Common disease states or conditions encountered in the physician's office, clinic, or acute care setting that may require respiratory care include upper respiratory tract infection, **pneumonia**, acute bronchitis, **asthma**, **chronic obstructive pulmonary disease (COPD)** (including emphysema and **chronic bronchitis**), pulmonary hypertension, heart failure, lung cancer, pulmonary fibrosis, pulmonary emboli, postoperative pulmonary complications, and acute respiratory failure (see Chapter 1).

TABLE 2-1
Types of Care Provided in the Respiratory Care Plan

Basic Respiratory Care
- Oxygen and medical gas therapy
- Humidity therapy
- Aerosol therapy
- Secretion management (airway clearance therapy)
- Sputum induction
- Management of bronchospasm and mucosal edema
- Lung expansion therapy
- Follow-up assessment and care plan modification and/or discontinuation

Critical Respiratory Care
- Invasive mechanical ventilatory support
- Noninvasive mechanical ventilatory support
- Physiologic monitoring
- Cardiac and hemodynamic support and monitoring
- Suctioning and airway care
- Airway intubation and management
- Arterial line insertion, management, and care
- Advanced cardiovascular life support
- Metabolic studies
- Extracorporeal life support (ECLS)
- Mechanical circulatory assistance
- Basic care in the intensive care setting

Diagnostic Testing
- Oximetry
- Arterial blood gases
- Pulmonary function testing
- Cardiac testing (e.g., electrocardiogram [ECG], invasive cardiology, cardiac catheterization laboratory)
- Ultrasound (bedside ultrasound, echocardiography, other)
- Sleep studies
- Exercise testing

Special Procedures
- Patient land and air transport
- Patient education
- Smoking cessation
- Pulmonary rehabilitation
- Cardiac rehabilitation
- Acute and chronic disease management

Respiratory Failure

Respiration refers to the exchange of oxygen (O_2) and carbon dioxide (CO_2) across the lung and pulmonary capillaries (external respiration) and at the tissue level (internal respiration). Respiratory failure, broadly defined, is an inability of the heart and lungs to provide adequate tissue oxygenation and/or carbon dioxide removal.[1,2] **Acute respiratory failure (ARF)** may be defined as a sudden decrease in arterial blood oxygen levels with or without carbon dioxide retention.[1,2] **Acute respiratory distress syndrome (ARDS)** is a form of respiratory failure that is characterized by oxygenation problems that generally do not respond well to basic **oxygen therapy** ($Pao_2/Fio_2 \leq 300$ on at least 5 cm of positive end-expiratory pressure [PEEP]). The term *hypoxemic respiratory failure* (aka "lung failure") is sometimes used when the primary problem is oxygenation.[3] Chapter 6 describes the assessment of a patient's oxygenation status. **Box 2-1** summarizes the various types of respiratory failure.

The most common reason for initiation of mechanical ventilatory support is *hypercapnic respiratory failure* (aka "ventilatory failure" or "pump failure").[3,5] **Acute ventilatory failure (AVF)** can be defined as a sudden rise in arterial CO_2 levels (as assessed by $Paco_2$) with a corresponding decrease in pH.[6] Respiratory muscle fatigue and an increased work of breathing may lead to AVF. Decreased ventilatory drive due to narcotic or sedative drug overdose, head trauma, or stroke can also result in AVF. Common disease states or conditions associated with the development of AVF include severe pneumonia, ARDS, massive or sub-massive pulmonary emboli, congestive heart failure (CHF), and pulmonary edema. More recently, coronavirus disease 2019 (COVID-19) caused by the SARS-CoV-2 virus has been associated with the development of severe viral pneumonia, respiratory failure, and ARDS in some patients. Shock, trauma, smoke or chemical inhalation, aspiration, and near drowning may also

BOX 2-1 Types of Respiratory Failure

Respiratory Failure

Respiratory failure is a general term that indicates the inability of the heart and lungs to provide adequate tissue oxygenation and/or carbon dioxide removal.

Acute Respiratory Failure

Acute respiratory failure may be defined as a sudden decrease in arterial blood oxygen levels (arterial partial pressure of oxygen [Pao_2] <50 to 60 mm Hg; arterial oxygen saturation [Sao_2] <88% to 90%), with or without carbon dioxide retention (arterial partial pressure of carbon dioxide [$Paco_2$] >45 mm Hg can be defined as CO_2 retention):

- *Hypoxemic respiratory failure* (lung failure) refers to a primary problem with oxygenation.
- *Hypercapnic respiratory failure* (pump failure) refers to a primary problem with ventilation. Hypercapnic respiratory failure is also known as *ventilatory failure*.

Ventilatory Failure

Ventilatory failure may be defined as an elevated $Paco_2$ (>45 to 50 mm Hg). An increased $Paco_2$ may also be called hypoventilation or hypercapnia:

- *Acute ventilatory failure* is defined as a sudden increase in arterial $Paco_2$ with a corresponding decrease in pH.

(*Continues*)

BOX 2-1 Types of Respiratory Failure (*Continued*)

- *Chronic ventilatory failure* is defined as a chronically elevated $PaCO_2$ with a normal or near-normal pH owing to metabolic compensation.
- *Acute-on-chronic ventilatory failure* is defined as a chronically elevated $PaCO_2$ followed by an acute increase in the $PaCO_2$ and a corresponding fall in pH.

Acute Respiratory Distress Syndrome

Acute respiratory distress syndrome (ARDS) is a form of noncardiogenic hypoxemic respiratory failure as defined (in part) by the PaO_2/FIO_2 ratio. Traditionally, the characteristics of ARDS were as follows:

- Bilateral pulmonary infiltrates on chest x-ray.
- Pulmonary capillary wedge pressure <18 mm Hg (i.e., pulmonary edema *not* due to cardiac failure or fluid overload).
- PaO_2/FIO_2 <300 was considered the borderline value for *acute lung injury*, or ALI. This is equivalent to a PaO_2 of less than 63 torr while breathing room air ($FIO_2 = 0.21$). Today, a PaO_2/FIO_2 ≤300 but >200 is considered to be mild ARDS (see Berlin Definition later). A PaO_2/FIO_2 <200 is equivalent to a PaO_2 of less than about the 42 torr while breathing room air ($FIO_2 = 0.21$).

More recently, the Berlin Definition of ARDS was adopted, which is based on symptom timing, chest imaging, and PaO_2/FIO_2 ratio while receiving at least 5 cm H_2O of PEEP or continuous positive airway pressure (CPAP).[4] This revised definition combines aspects of ALI and ARDS and requires (1) identification of respiratory symptoms within 1 week of new or worsening symptoms or a known clinical insult; (2) bilateral opacities upon chest imaging (chest x-ray or computed tomography [CT] scan); (3) opacities that cannot be due to lobar collapse, lung collapse, pulmonary effusion, or pulmonary nodules; (4) pulmonary edema that cannot be due to cardiac failure or fluid overload as assessed by echocardiography or other measures to exclude hydrostatic edema (e.g., PCWP <18 mm Hg); and (5) PaO_2/FIO_2 ≤300 mm Hg with PEEP or CPAP ≥5 cm H_2O where:

- PaO_2/FIO_2 ≤300 mm Hg but >200 mm Hg—mild
- PaO_2/FIO_2 ≤200 mm Hg but >100 mm Hg—moderate
- PaO_2/FIO_2 ≤100 mm Hg—severe

FIO_2, fraction of inspired oxygen; PEEP, positive end-expiratory pressure; PCWP, pulmonary capillary wedge pressure. If altitude is higher than 1000 m, then correction factor should be calculated as follows: [PaO_2/FIO_2 × (barometric pressure/760)].

Data from: ARDS Definition Task Force, Ranieri VM, Rubenfeld GD, Thompson BT, Ferguson ND, Caldwell E, Fan E, Camporota L, Slutsky AS. Acute respiratory distress syndrome: the Berlin Definition. JAMA. 2012;307(23):2526-2533. doi: 10.1001/jama.2012.5669.

cause AVF. Acute exacerbation of COPD, acute severe asthma, severe burns, upper airway obstruction, obesity, and thoracic deformity all predispose patients to the development of AVF. Neuromuscular disease such as Guillain-Barré syndrome, myasthenia gravis, and spinal cord injury may also precipitate AVF.

Chronic ventilatory failure (CVF) (aka "chronic hypercapnia") may be defined as a chronically elevated $PaCO_2$ with a normal (compensated) or near-normal pH.[6] The most common cause is severe COPD, although not all COPD patients develop CVF. Ventilatory failure usually suggests that fewer than 25% of alveoli are functioning. Acute pneumonia in COPD patients often will result in AVF that resolves as the pneumonia improves and inflammatory cells are cleared from the airway. Other chronic lung diseases, such as late-stage cystic fibrosis, severe interstitial lung disease, and obesity-hypoventilation syndrome, are associated with the development of CVF. Evaluation of ventilation is described in Chapter 7.

Respiratory failure requires careful patient assessment followed by the development and implementation of the respiratory care plan. Common causes of respiratory failure are listed in **Box 2-2**. **Clinical Focus 2-1** provides an example of a specific type of respiratory failure.

Respiratory Care Plan Development

The process for respiratory care plan development generally includes the receipt of an order for a specific type of respiratory care or for a respiratory care consult. The process for developing a respiratory care plan may begin when a patient enters the healthcare setting with a problem or complaint. Sometimes the need for respiratory care is not immediately apparent and, in the acute care setting, patients often require respiratory care at some point following admission to the hospital.

RC Insight

Developing a respiratory care plan requires a careful patient assessment

Following initial assessment and verification of the patient's problem or diagnosis by the physician, nurse practitioner, or physician assistant, an order for respiratory care may be written. Upon receipt of an order, the respiratory care clinician performs a medical records review, patient interview, and physical assessment.

BOX 2-2 Common Causes of Respiratory Failure

Oxygenation Problems

- Low ventilation/perfusion ratio (i.e., $\dot{V}/\dot{Q}$ <1 but >0)
  - Underventilation with respect to pulmonary perfusion
  - Examples: asthma, emphysema, COPD, cystic fibrosis, bronchiectasis
- Pulmonary shunt ($\dot{V}/\dot{Q} = 0$)
  - No ventilation with respect to pulmonary perfusion
  - Examples: ARDS, atelectasis, severe pneumonia
- Diffusion problems
  - Impaired diffusion due to increased diffusion distance, diffusion block
  - Example: early pulmonary fibrosis
- Hypoventilation
  - Increases in $Paco_2$ result in a corresponding decrease in Pao_2
- Low blood oxygen content
  - Low Pao_2, Sao_2, or hemoglobin
  - Examples:
    - Low Pao_2 due to low $\dot{V}/\dot{Q}$, shunt, diffusion problems, or hypoventilation
    - Low hemoglobin (anemia) or abnormal hemoglobin (e.g., elevated carboxyhemoglobin due to carbon monoxide poisoning)
- Increased pulmonary dead space
  - Examples: pulmonary embolus, obliteration of the pulmonary capillaries (as in severe emphysema)

Ventilation Problems

- Acute ventilatory failure (AVF)
  - A sudden increase in $Paco_2$ with a corresponding decrease in pH
  - Examples of conditions associated with AVF:
    - ARDS, severe pneumonia
    - Shock, chest trauma, pneumothorax, head trauma, stroke, spinal cord injury, smoke or chemical inhalation, aspiration, near drowning
    - Sedative or narcotic drug overdose, paralytic drugs, deep anesthesia
    - Respiratory muscle fatigue and increased work of breathing due to acute exacerbation of COPD, acute severe asthma, severe obesity, thoracic deformity
    - Neuromuscular disease associated with respiratory failure, such as Guillain-Barré, amyotrophic lateral sclerosis (ALS), myasthenia gravis, polio, critical illness/steroid myopathy, botulism, tetanus
    - Patients recovering from abdominal or thoracic surgery who may need mechanical ventilatory support
- Chronic ventilatory failure
  - A chronically elevated $Paco_2$ with normal or near-normal pH
  - Examples: chronic bronchitis, severe COPD, obesity-hypoventilation syndrome

COPD, chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome; $Paco_2$, arterial partial pressure of carbon dioxide; Pao_2, partial pressure of oxygen, arterial; Sao_2, oxygen saturation.

Data from West JB. Acute respiratory failure. In: West JB, editor. Pulmonary physiology and pathophysiology: an integrated, case-based approach, 2nd ed. Philadelphia: Lippincott, Williams & Wilkins; 2007:116–133.

CLINICAL FOCUS 2-1 Respiratory Failure

A 30-year-old male was admitted to the hospital with chest trauma following a motor vehicle accident. The patient's increasing respiratory distress, tachypnea, and hypoxemia while breathing room air led to intubation and the initiation of mechanical ventilation. The chest x-ray shows bilateral pulmonary infiltrates; however, there is no evidence of cardiogenic pulmonary edema or fluid overload. Current arterial blood gases while being supported in the assist-control mode of ventilation with an Fio_2 of 0.60 and 5 cm H_2O PEEP are:

pH: 7.36
$Paco_2$: 36 mm Hg
Pao_2: 62 mm Hg
Sao_2: 90%
HCO_3^-: 20 mEq/L
B.D.: −5 mEq/L

How would you describe the patient's respiratory condition? (Hint: Before describing the patient's condition, review the definitions and descriptions of respiratory failure found in Box 2-1).

The patient is in acute respiratory failure. The patient has new bilateral pulmonary infiltrates, no evidence of cardiogenic pulmonary edema or fluid overload, and a Pao_2/Fio_2 ratio of 103, which is consistent with a diagnosis of moderate ARDS.

Fio_2, fractional concentration of inspired oxygen; PEEP, positive end-expiratory pressure; $Paco_2$, arterial partial pressure of carbon dioxide; Pao_2, partial pressure of oxygen, arterial; Sao_2, oxygen saturation; HCO_3^-, bicarbonate; B.D., base deficit; ARDS, acute respiratory distress syndrome.

The definition of ARDS was first clarified by a 1992 American-European Consensus Conference. Rubenfeld GD, Herridge MS. Epidemiology and outcomes of acute lung injury. Chest 2007;131(2):554–562.

Bedside measurement of oxygen saturation (Spo_2) and basic pulmonary function parameters may be performed. Following this assessment, the respiratory care clinician may then select the appropriate care based on the patient's condition. The goal is to optimize the match between the care needed and the care "menu," or treatment options that are available. Basic respiratory care options include techniques to improve oxygenation and manage secretions, treatment for bronchospasm and mucosal edema, and **lung expansion therapy**.

A typical basic respiratory care treatment menu is provided in **Table 2-2**. Following selection of a

TABLE 2-2
Respiratory Care Treatment Menu

Oxygenation
- Nasal cannula
- Oxygen masks (simple/partial/nonrebreather)
- High-flow systems ("Venturi" masks, large-volume air-entrainment nebulizers, high-flow nasal cannula [HFNC])
- CPAP by mask
- PEEP (may require invasive mechanical ventilation)

Bronchospasm/Mucosal Edema
- Bronchodilator therapy (SVN, MDI, DPI, SMI)
  - Short-acting beta-2 agonists (SABA, e.g., albuterol [Proventil HFA, Ventolin HFA]; levalbuterol [Xopenex])
  - Short-acting muscarinic antagonist (SAMA, e.g., ipratropium [Atrovent])
  - Long-acting beta-2 agonist (LABA, e.g., salmeterol [Serevent], formoterol [Foradil], formoterol for nebulizers [Perforomist], arformoterol [Brovana], indacaterol [Arcapta], olodaterol [Striverdi])
  - Long-acting muscarinic antagonist (LAMA; e.g., tiotropium [Spiriva], umeclidinium [Incruse Ellipta])
  - Revefenacin (Yupelri solution)
  - Combination bronchodilators (e.g., SAMA/SABA combinations such as ipratropium/albuterol [Combivent] and LAMA/LABA combinations, including umeclidinium/vilanterol [Anoro], tiotropium/olodaterol [Stiolto], glycopyrrolate/formoterol [Bevespi], and glycopyrronium/indacaterol [Utibron])
- Inhaled corticosteroids (ICS) (fluticasone [Flovent], flunisolide [Aerobid], budesonide [Pulmicort], beclomethasone [Qvar])
- Combination bronchodilator/corticosteroid medications (e.g., ICS/LABA: fluticasone and salmeterol [Advair]); fluticasone and vilanterol (Breo); budesonide and formoterol (Symbicort); and ICS/LAMA/LABA: fluticasone, umeclidinium and vilanterol (Trelegy)
- Antiasthmatic aerosol agents (cromolyn, etc.)

Ventilation
- Noninvasive mechanical ventilation (NIV, BiPAP)
- Invasive mechanical ventilation

Lung Expansion Therapy
- Cough and deep-breathing techniques
- Suctioning
- Incentive spirometry
- IPPB

Secretion Management (Airway Clearance/Bronchial Hygiene)
- Directed cough and deep-breathing instruction
- Inhaled agents for airway clearance (e.g., DNase [dornase alpha], hypertonic saline [3% to 7% NaCl], mannitol)
- Suctioning (NT, ET, tracheostomy suctioning)
- Chest physiotherapy (postural drainage, percussion, vibration)
- Positive expiratory pressure (PEP)
- Oscillatory PEP (e.g., acapella flutter valve)
- High-frequency chest wall oscillation (percussion vest)
- High-volume bland aerosol therapy (ultrasonic nebulizer, heated large-volume nebulizer)
- Mucus-controlling agents (mucolytics)

Frequency of Treatment Options
- Continuous
- Every 1 to 2 hours
- Every 4 hours
- Every 6 hours
- Four times per day
- Three times per day
- Two times per day
- Daily
- As needed

Sputum Induction/Obtain Specimen
- Directed cough
- Hypertonic saline aerosol
- Suctioning (NT, ET, tracheostomy suctioning)

Aerosolized (Inhaled) Antibiotics (CF, Bronchiectasis)
- Tobramycin
- Aztreonam lysine
- Colistin
- Others (e.g., gentamicin, ciprofloxacin)

CPAP, continuous positive airway pressure; PEEP, positive end-expiratory pressure; NIV, noninvasive ventilation; BiPAP, bilevel positive airway pressure; NT, nasotracheal; ET, endotracheal; CF, cystic fibrosis; SVN, small volume nebulizer; MDI, metered-dose inhaler; DPI, dry powder inhaler; SMI, soft mist inhaler; IPPB, intermittent positive pressure ventilation.

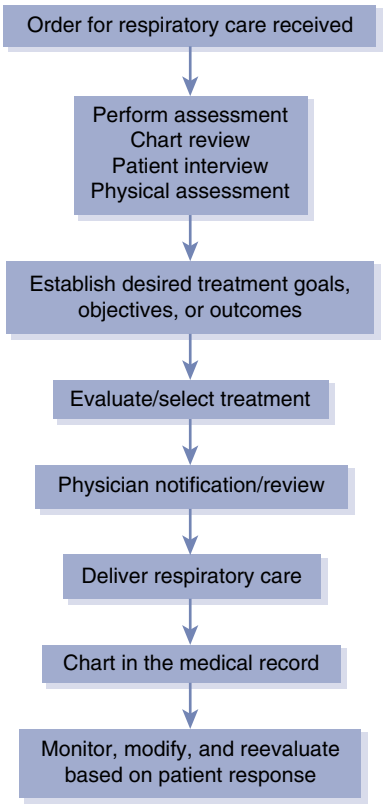

FIGURE 2-1 Steps in the development and implementation of the respiratory care plan.

respiratory care treatment regimen, the patient's physician should be notified and given the opportunity to review and/or modify the care plan. The care is then delivered. The patient is monitored, and the care plan is reevaluated based on the patient's response to therapy. **Figure 2-1** summarizes the steps in respiratory care plan development and implementation.

Goals of Respiratory Care Plans

Respiratory care plans may be developed for basic and critical respiratory care, diagnostic testing, and specialized procedures (see Table 2-1). Goals of the respiratory care plan may include maintaining or improving oxygenation and ventilation, managing secretions, treating or preventing bronchospasm and mucosal edema, treating infection and treating and/or preventing atelectasis and pneumonia. Basic respiratory care plans may include oxygen therapy, secretion management, treatment of bronchospasm and mucosal edema, and lung expansion therapy.

Diagnostic respiratory care procedures include techniques to assess oxygenation, ventilation, acid–base balance, and pulmonary function and to obtain sputum samples (e.g., sputum induction) for Gram stain, culture, and cytologic examination. Critical respiratory care may include mechanical ventilatory support, airway care, physiologic monitoring, cardiovascular stabilization, mechanical circulatory assistance, and extracorporeal membrane oxygenation (ECMO). We will now turn to the development of specific respiratory care plans based on an assessment of the patient's needs and the related goals of therapy.

Key Elements of a Respiratory Care Plan

The key elements of a basic respiratory care plan are listed in **Box 2-3** and include the goals of therapy, devices, medications, methods, gas source, and frequency of administration. Assessment of basic respiratory care should note improvement in oxygenation and ventilation, work of breathing, breath sounds, and, in some cases, pulmonary function and blood gases. **Box 2-4** lists the key elements of a respiratory care plan for mechanical ventilatory support.

Maintain Adequate Tissue Oxygenation

Oxygen therapy is indicated for documented or suspected **hypoxemia**, severe trauma, acute myocardial infarction (MI), and immediate postoperative recovery.[7] It also may be indicated to support the patient with chronic lung disease during exercise and to prevent or treat right heart failure (cor pulmonale) due to chronic pulmonary hypertension.[7] A Pa_{O_2} <60, Sa_{O_2} <90%, and/or an Sp_{O_2} <90% to 92% are considered clear indications for oxygen therapy in most patients.[7] Exceptions to this rule include patients with chronic carbon dioxide retention and the premature neonate. A critical value in the COPD patient may be a Pa_{O_2} of ≤55 torr with an Sp_{O_2} of ≤88% while breathing room air or a Pa_{O_2} of 56 to 59 and an Sa_{O_2} <89% in the presence of cor pulmonale, pulmonary hypertension, CHF, or erythrocythemia with a hematocrit >56.[8] A critical Pa_{O_2} for the newborn may be a Pa_{O_2} <50 torr and/or an Sp_{O_2} <88% or a capillary P_{O_2} <40 torr.[9]

Hypoxemia should be suspected whenever the patient is exhibiting the signs and symptoms of hypoxia. Initial signs of hypoxia include tachycardia, increased blood pressure, tachypnea, hyperventilation, dyspnea, and use of accessory muscles. Other early manifestations of hypoxia include restlessness, disorientation, dizziness, excitement, headache, blurred vision, impaired judgment, and confusion. Clinical manifestations of severe hypoxia may include slow, irregular respirations; bradycardia; hypotension; dysrhythmias; loss of consciousness; somnolence; convulsions; and coma. These later findings are more common when hypoxia and hypercapnia coexist. Severe hypoxia may lead to respiratory and/or cardiac arrest. The respiratory care clinician should obtain an Sp_{O_2} or arterial blood gas study in order to confirm the presence of hypoxemia. The indications for oxygen therapy in the acute care setting are summarized in **Box 2-5**.

BOX 2-3 Key Elements of a Basic Respiratory Care Plan

Goals of Therapy

- Maintain adequate tissue oxygenation and/or alveolar ventilation.
- Treat/prevent bronchospasm and/or mucosal edema.
- Deliver anti-inflammatory or antiasthmatic agents.
- Manage secretions, promote secretion clearance.
- Treat infection (e.g., *Pseudomonas aeruginosa* infection in cystic fibrosis).
- Induce sputum for testing (e.g., Gram stain, culture, cytology).
- Prevent or treat atelectasis.

Device or Procedure

- Oxygen therapy (nasal cannula, air-entrainment mask, other masks or high-flow nasal cannula [HFNC])
- Aerosol medication via SVN, MDI, DPI, or SMI
- Incentive spirometry
- IPPB
- Directed cough
- Suctioning
- Chest physiotherapy (postural drainage and chest percussion)
- Positive expiratory pressure (PEP)
- Oscillatory PEP (e.g., acapella flutter valve)
- High-frequency chest wall oscillation (percussion vest)
- Intrapulmonary percussive ventilation (IPV, Percussionaire)
- High-volume bland aerosol with or without supplemental oxygen
- Mechanical ventilatory support (invasive and noninvasive ventilation; see also Box 2-4)

Medications

- Bronchodilators (e.g., short-acting beta-2 agonists [SABA], short-acting muscarinic antagonists [SAMA], long-acting beta-2 agonists [LABA], or long-acting muscarinic antagonists [LAMA])
- Mucolytics (*N*-acetylcysteine [Mucomyst]; dornase alfa, aka DNase [Pulmozyme])
- Anti-inflammatory agents and decongestants (inhaled corticosteroids [ICS], racemic epinephrine, others)
- Combined medications (e.g., LABA and LAMA; LABA and ICS; LABA, LAMA, and ICS)
- Antiasthmatic agents (cromolyn sodium [Intal], nedocromil sodium [Tilade])
- Bland aerosol (normal saline [0.9% NaCl], one-half normal saline [0.45% NaCl], sterile distilled water)
- Other inhaled airway clearance agents (hypertonic saline [3% to 7% NaCl], mannitol)

Method or Appliance

- Mask, mouthpiece, mouth seal, tracheostomy mask, nose clips, holding chamber (e.g., Aero-Chamber), or spacer

Gas Source, Flow, and/or Pressure

- Oxygen or compressed air
- Liter flow and/or F_{IO_2}
- Pressure (IPPB, IPV)

Frequency and Duration of Therapy

- Twice daily, three times daily, four times daily, every 6 hours, every 4 hours, every 2 hours, every 1 hour, continuous, as needed, etc.
- Duration of therapy in minutes or continuous

Volume Goals

- Incentive spirometry minimum of one-third of predicted IC (1/3 × IBW in kg × 50 mL/kg)
- IPPB minimum of one-third predicted IC (or at least 10 mL/kg)

Assessment

- Improvement and/or reversal of clinical signs and symptoms of respiratory failure
- Reversal of the manifestations of hypoxia and/or hypoventilation
- Decreased work of breathing
- Decreased cardiac work
- Improved breath sounds (air movement, wheezing, rhonchi, crackles)
- Pulse oximetry and arterial blood gases
- Bedside pulmonary function (respiratory rate, volumes, inspiratory force, PEF, IC, FVC, FEV_1)
- Chest x-ray or other imaging techniques

SVN, small volume nebulizer; MDI, metered-dose inhaler; DPI, dry powder inhaler; SMI, soft mist inhaler; IPPB, intermittent positive pressure breathing; F_{IO_2}, fractional concentration of inspired oxygen; IC, inspiratory capacity; IBW, ideal body weight; PEF, peak expiratory flow rate; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 second.

Data from West JB. Acute respiratory failure. In: West JB. Pulmonary physiology and pathophysiology: an integrated, case-based approach, 2nd ed. Philadelphia: Lippincott, Williams & Wilkins; 2007: 116-133.

BOX 2-4 Key Elements of a Respiratory Care Plan for Mechanical Ventilatory Support

Goals of Therapy

- Ensure adequate tissue oxygenation
- Provide adequate alveolar ventilation and CO_2 removal
- Restore and maintain acid–base homeostasis
- Maintain adequate circulation, blood pressure, and cardiac output
- Treat bronchospasm/mucosal edema/excess secretions
- Maintain lung volumes/prevent or treat atelectasis
- Reduce the work of breathing
- Ensure patient safety and comfort
- Minimize harmful side effects and complications
- Promote liberation of the patient from the ventilator

Device or Procedure

- Volume ventilators
- Pressure ventilators (includes NIV/BiPAP devices)
- High-frequency ventilators
- Humidifiers
- Nebulizers
- MDI and holding chamber
- Positive pressure masks (nasal/oral)
- Artificial airways (endotracheal and tracheostomy tubes)
- Suctioning equipment

Medications

- Bronchodilators, anti-inflammatory agents, decongestants, antiasthmatic drugs
- Drugs to treat infection
- Drugs to support circulation, cardiac function, blood pressure
- Sedatives, tranquilizers, pain medications, paralytic agents

Method or Appliance

- Mask (oral/nasal)
- Endotracheal tube
- Tracheostomy tube

Mode of Ventilation

- Invasive or noninvasive ventilation (NIV)
- Continuous mandatory ventilation (CMV)—pressure control or volume control
- Intermittent mandatory ventilation (IMV)—pressure control or volume control
- Other modes and terminology (e.g., assist/control, volume-limited ventilation, pressure-limited ventilation, pressure support ventilation, SIMV, SIMV with pressure support, PRVC, VS, ASV, APRV, PAV, NAVA, BiPAP, HFV)
- Breath initiation (time or patient trigger)
- Inspiratory termination (volume, time, pressure, or flow)

Gas Source, Flow, and/or Pressure

- Oxygen concentration
- Patient trigger (pressure or flow trigger)
- Inspiratory flow or time
- Termination of inspiration (pressure, volume, or flow)

Frequency and Duration of Therapy

- Continuous mechanical ventilatory support
- Intermittent support (ventilator weaning, night only, or for acute distress)

Volume and Pressure

- Volume ventilation (mL/kg IBW or mL)
- Inspiratory pressure or pressure limit
- Baseline pressure (PEEP or CPAP)
- Pressure support for "spontaneous" breaths

Assessment

- Improvement and/or reversal of clinical signs and symptoms
- Reversal of the manifestations of hypoxia and/or hypoventilation
- Cardiovascular/hemodynamics (pulse, blood pressure, cardiac output, CVP, other)
- Work of breathing
- Improved breath sounds (air movement, wheezing, rhonchi, crackles)
- Pulse oximetry and arterial blood gases
- Bedside pulmonary function (spontaneous respiratory rate, volumes, RSBI, inspiratory force, IC, VC)
- Chest x-ray or other imaging techniques

BiPAP, bilevel positive airway pressure; MDI, metered-dose inhaler; SIMV, synchronized intermittent mandatory ventilation; PRVC, pressure regulated volume control; VS, volume support; ASV, adaptive support ventilation; APRV, airway pressure release ventilation; PAV, proportional assist ventilation; NAVA, neurally adjusted ventilatory assist; HFV, high-frequency ventilation; IBW, ideal body weight; PEEP, positive end-expiratory pressure; CPAP, continuous positive airway pressure; CVP, central venous pressure; RSBI, rapid shallow breathing index; IC, inspiratory capacity; VC, vital capacity.

BOX 2-5 Indications for Oxygen Therapy

- Documented hypoxemia (Spo_2 or arterial blood gases):
  - Adults and children: Pao_2 <60 and/or Spo_2 <90
  - Neonates (<28 days): Pao_2 <50 and/or Spo_2 <88% or a capillary Po_2 <40 torr
- Suspected hypoxemia based on patient condition and/or clinical manifestations of hypoxia (follow with Spo_2 or arterial blood gas measurement)*
  - Clinical manifestations of hypoxia include:
    - Tachycardia, increased blood pressure, dysrhythmias
    - Dyspnea, tachypnea, hyperventilation, use of accessory muscles
    - Restlessness, disorientation, dizziness, excitement, headache, blurred vision, impaired judgment, and confusion
  - Clinical manifestations of severe hypoxia may include:
    - Slowed, irregular respirations
    - Bradycardia, hypotension
    - Confusion, loss of consciousness, somnolence, convulsions, or coma
- Severe trauma
- Acute myocardial infarction
- Postoperative recovery

Treat or prevent pulmonary hypertension secondary to chronic hypoxemia:

- Pao_2 ≤55 and/or Spo_2 of ≤88% while breathing room air in patients with COPD

or

- COPD patients with cor pulmonale or hematocrit >56, Pao_2 of 56 to 59, Sao_2 <89%, and preexisting pulmonary hypertension

*Hypoxemia should be suspected in the presence of the clinical manifestations of hypoxia.

Spo_2, arterial blood oxygen saturation; Pao_2, partial pressure of oxygen, arterial; COPD, chronic obstructive pulmonary disease.

Once it is established that oxygen therapy is required, the respiratory care clinician must decide on the appropriate equipment, the correct oxygen flow and/or FIo_2, and how the therapy will be assessed. In general, the lowest FIo_2 needed to ensure adequate tissue oxygenation should be chosen. Generally, this means a target Pao_2 of 60 to 100 with an Spo_2 of 92% to 98% for most patients, with the exception of the COPD patient and the premature infant.

One should avoid high oxygen levels (>50% to 60%) for extended periods of time because of the threat of oxygen toxicity, absorption atelectasis, and depression of ciliary and/or leukocytic function.[7,9] If high levels of oxygen are needed for more than short periods of time, alternative methods to improve oxygenation should be considered.

Some but not all COPD patients develop chronic CO_2 retention, sometimes referred to as CVF or chronic hypercapnia. Excessive oxygen levels in patients who are chronic CO_2 retainers may lead to worsened hypercapnia in some, and this is thought to be largely due to worsening $\dot{V}/\dot{Q}$ mismatch and increased dead space ventilation. The Pao_2 and Spo_2 values which may trigger this *oxygen-induced hypercapnia* are thought to be when Pao_2 exceeds 60 torr and Spo_2 >90%.[7] The most recent Global Initiative for Chronic Obstructive Lung Disease (GOLD) Report guidelines suggest that oxygen therapy for the COPD patient with chronically elevated $Paco_2$ levels should be targeted at maintaining a Pao_2 of 60 to 70 torr with an Sao_2 of 88% to 92% in order to avoid oxygen-induced hypercapnia.[10] However, in hypoxemic COPD patients with severe chronic hypercapnic respiratory failure, consider titration to a Pao_2 goal of 55 to 60 mm Hg with an Spo_2 of 88% to 90% to avoid worsening hypercapnia.[11]

For long-term oxygen therapy (LTOT) in the COPD patient at rest, a Pao_2 goal of 60 to 65 mm Hg or Spo_2 of 90% to 92% has been suggested.[12]

Some patients with chronic lung disease experience hypoxemia with increased levels of activity, and the **six-minute walk test** (6MWT; see Chapter 12) is sometimes used to titrate oxygen requirements during exercise for these patients. For example, a patient who does not require oxygen at rest begins walking vigorously on a standard 30-m course while monitoring Spo_2. If Spo_2 falls below an acceptable level (e.g., Spo_2 ≤88%), O_2 therapy by nasal cannula is started at 2 L/min and the test resumed. If Spo_2 once again falls below an acceptable level, O_2 flow is increased and the test resumed. This procedure is repeated until the O_2 flow needed to maintain an acceptable Spo_2 during exercise is identified.

Retinopathy of prematurity (ROP) is a vascular disorder of the eye that may lead to visual impairment or blindness. ROP is thought to be caused by hypoxia, hyperoxia, and/or hypotension in very premature infants. Providing high oxygen levels to premature infants has been associated with the development of ROP and in

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High concentrations of oxygen (>50%–60%) for extended periods of time should be avoided, unless they are necessary to correct severe hypoxemia.