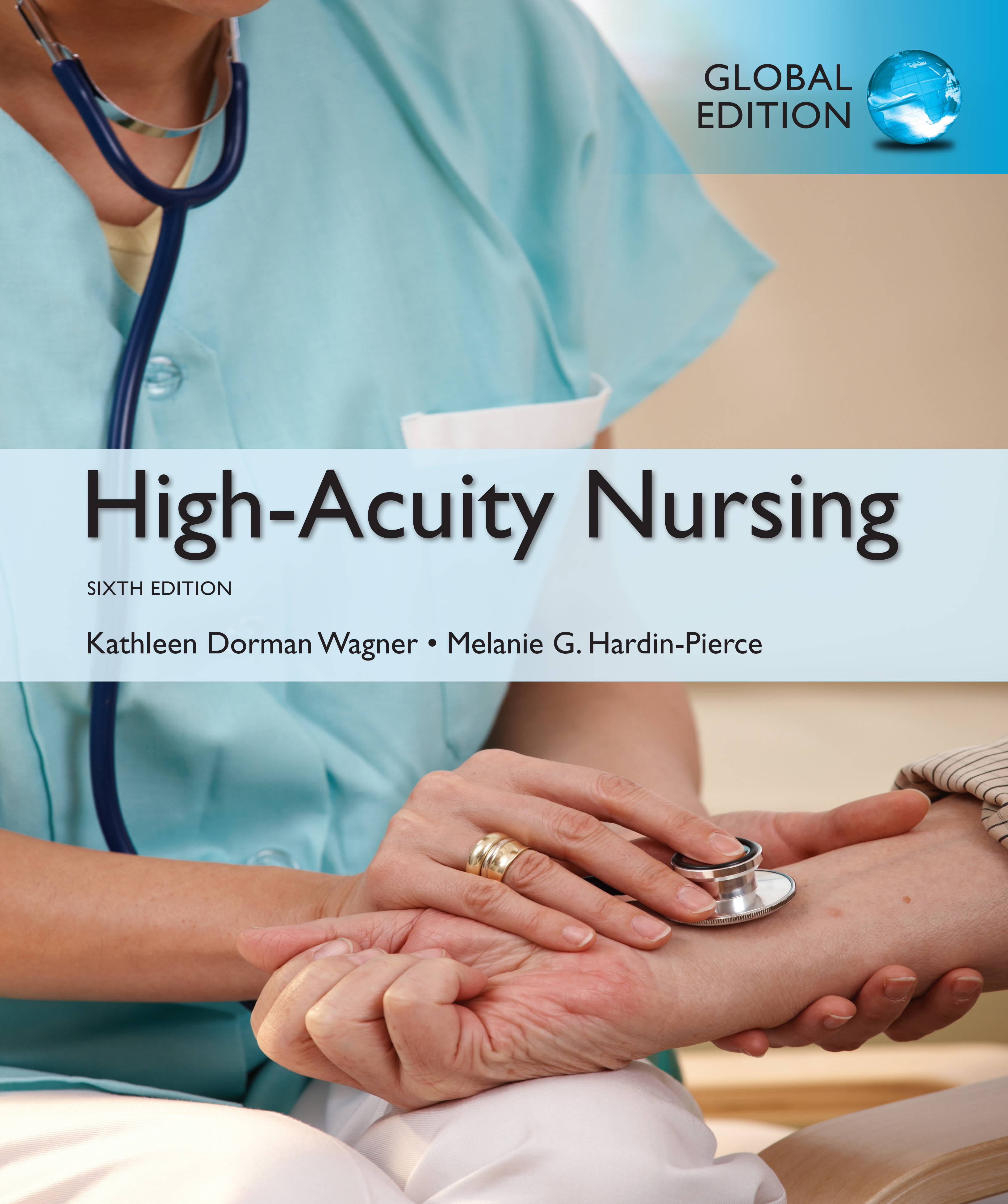

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High-Acuity Nursing

SIXTH EDITION

Kathleen Dorman Wagner • Melanie G. Hardin-Pierce

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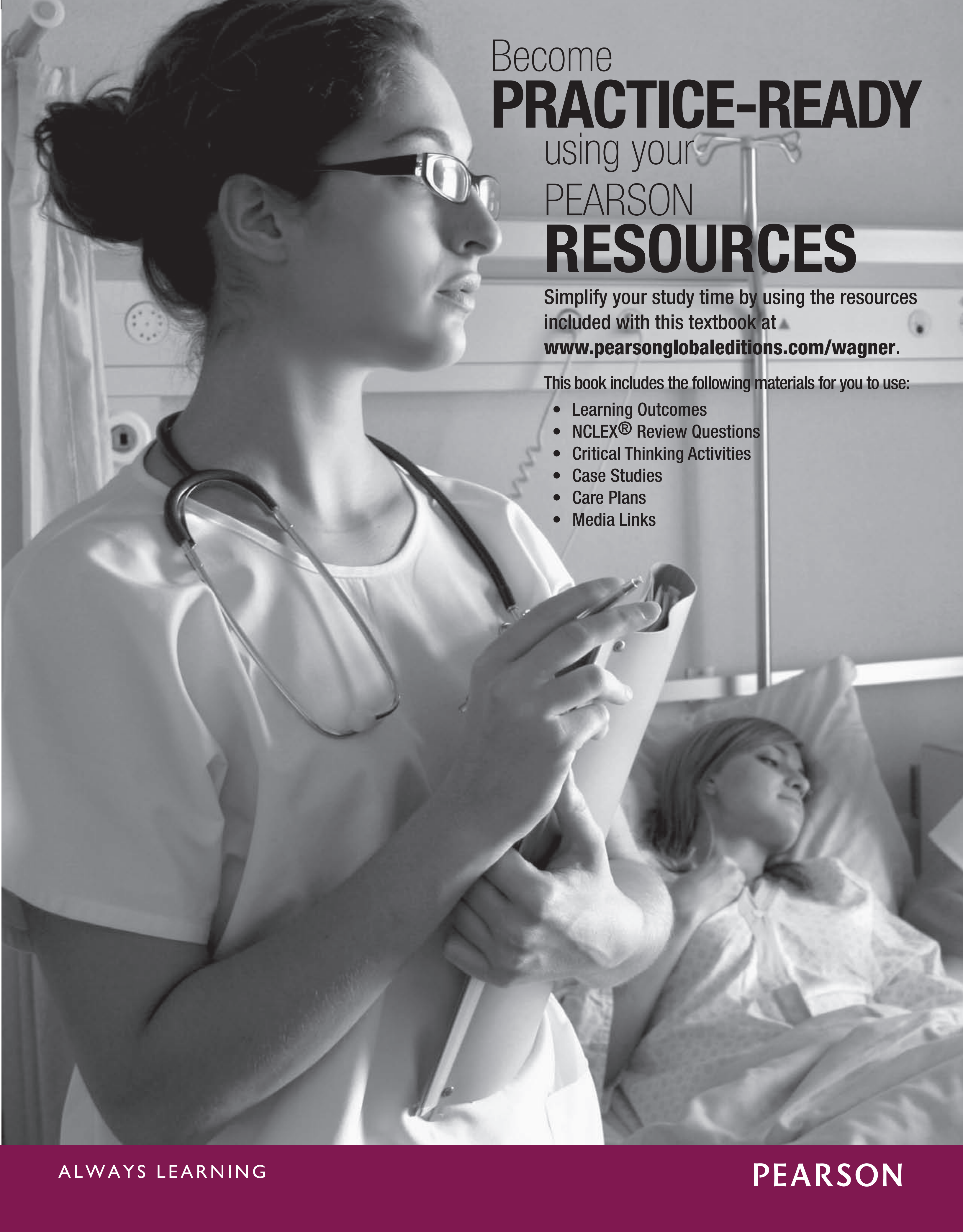
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When an acid–base imbalance exists, acidosis may cause a lower saturation reading and alkalosis may cause a higher reading because of shifts in the oxyhemoglobin dissociation curve. Severe peripheral vasoconstriction creates a low-flow arterial state in which the pulsatile force is too weak to be accurately read by pulse oximetry. When severe vasoconstriction is present, the sensor may read more accurately if it is removed from distal sites (fingers, toes) and attached to a more central location, such as the bridge of the nose or the earlobe. The hypothermic patient generally requires warming to normothermic levels before pulse oximetry can be used. In addition, patients who have abnormal levels of carboxyhemoglobin (carbon dioxide and carbon monoxide) may have a high Spo_2 even though the oxyhemoglobin level is very low. This false reading occurs because pulse oximetry cannot differentiate carboxyhemoglobin from oxyhemoglobin.

Capnography

Capnometry is the numeric measurement of carbon dioxide (CO_2). **Capnography** is the noninvasive graphic display of CO_2 concentration that is exhaled by the patient during breathing (Nikolova-Todorova, 2008). It is commonly referred to as capnography or end-tidal CO_2 monitoring. Capnography results in a single-value capnometric measurement called the $ETCO_2$ (end-tidal CO_2). Continuous bedside monitoring of CO_2 is accomplished using infrared light absorption or mass spectrometry. Infrared analyzers measure carbon dioxide based on its strong absorption band at a distinctive wavelength. A **capnogram** displays the capnography measurements as a continuous waveform that can be read, breath by breath, throughout the breathing cycle. CO_2 can be sampled using either sidestream or mainstream techniques. ■ Fig. 10–18 shows an example of a capnograph monitor.

Capnography Applications

Capnography is commonly used to monitor the adequacy of ventilation in surgical and procedural anesthesia, postoperative recovery, critical care units, and emergency departments (EDs). New ACLS guidelines for CPR and emergency care call for the use of capnography to confirm endotracheal tube placement and monitor the adequacy of ventilation (James, 2011). The Agency for Healthcare Research and Quality (AHRQ) recommends monitoring oxygenation (using pulse oximetry and respiratory rate) and ventilation (using capnography) for postoperative patients receiving patient-controlled analgesia (PCA) to reduce the risk of potentially life-threatening respiratory depression (Maddox, Oglesby, Williams, Fields, & Danello, 2008). Other applications include the detection of mechanical ventilator problems and confirmation of enteric feeding tube placement.

■ **FIGURE 10–18** Example of a capnograph monitor. Measures and displays end tidal carbon dioxide ($ETCO_2$), SpO_2, and respiratory and pulse rates.
(Image courtesy of Respironics, Inc., Murrysville, PA)

End-tidal carbon dioxide monitoring may be used to assess ventilatory status and provide an early warning of changes in ventilation. An abnormally low $ETCO_2$ (less than 30 mm Hg) is most commonly associated with hyperventilation, hypothermia, pulmonary embolism, or decreased cardiac output (Slesinger, 2012). Increased $ETCO_2$ (greater than 44 mm Hg) is associated with increased production of carbon dioxide (e.g., fever or increased cardiac output) or hypoventilation (e.g., respiratory center depression or neuromuscular diseases).

The usefulness of bedside capnography is not without limitations. In patients with morbid obesity, severe pulmonary edema, or ventilation–perfusion abnormalities, the $ETCO_2$ may not accurately reflect $Paco_2$ (Vissers & Danzl, 2011). However, it may still be helpful if a correlation between $Paco_2$ and $ETCO_2$ can be established and used for trending. Unfortunately, many high-acuity patients develop ventilation–perfusion abnormalities, which may limit the usefulness of $ETCO_2$ monitoring.

Types of Capnography

CO_2 is sampled for capnography in three ways. Infrared analyzers are applied either sidestream or mainstream, and colorimetric capnography uses pH-sensitive paper to estimate $ETCO_2$ ranges.

Sidestream. When a sidestream analyzer is used, a small volume of exhaled gas is diverted from the main airway circuit through a small tube and is analyzed in a special chamber apart from the airway circuit. The major disadvantage to using sidestream gas samples is that the values are indirect estimated measurements. The major advantage is that it can be used with patients who are not intubated.

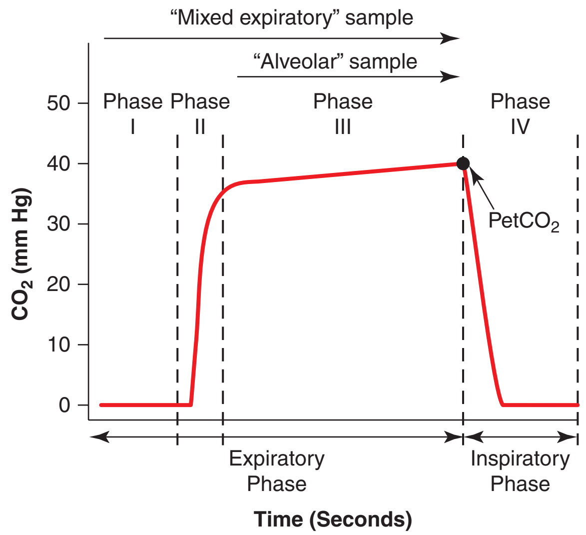
Mainstream. Mainstream infrared analyzers are placed in-line as part of the airway circuit and continuously measure the $ETCO_2$ directly, in real time (Slesinger, 2012). The major disadvantage to the mainstream technique is that it requires the patient to be intubated.

Colorimetric Capnography. Colorimetric capnography uses pH-sensitive paper that changes color based on the patient's exhaled pH to represent a range of $ETCO_2$ (Galbois et al., 2011). It is most commonly used in the ED to assess for proper endotracheal (ET) tube placement (Vissers & Danzl, 2011); however, it is also used in the field by emergency squads and in ICU settings. A CO_2 detector device is attached to the ET tube following tube insertion, the patient is given six breaths, and the device is read at full-end expiration (Nellcor, 2012). The device rapidly responds to the patient's exhaled CO_2 with three color ranges. For example, with a Nellcor EASYCAP II (Nellcor, Boulder, CO), the detector device has a color range of purple to yellow with interpretation as follows:

- Color range A (purple): 0.03% to less than 0.5% $ETCO_2$ (less than 4 mmHg CO_2); interpretation: ET tube is not in the trachea
- Color range B (brown): 0.5% to less than 2% $ETCO_2$ (4 to less than 15 mmHg CO_2); interpretation: ET tube may be in the esophagus, or patient may have hypocarbia or low pulmonary blood flow
- Color range C (yellow): 2% to 5% $ETCO_2$ (15 to 38 mmHg CO_2); interpretation: ET tube is properly located in the trachea (Nellcor, 2012; Galbois et al., 2011)

While colorimetric capnography is adequate for assessing proper ET tube placement, it does not provide precise $ETCO_2$ data and therefore has limited applications (Vissers & Danzl, 2011).

The Capnogram The capnogram is the pattern that is visible on the capnography screen. A normal capnogram shows an $ETCO_2$ within several mm Hg of arterial $Paco_2$ at the end of the plateau phase (the end-tidal CO_2). In a normal capnogram, the carbon dioxide concentration is zero at the beginning of expiration, gradually rising until it reaches a plateau (■ Fig. 10–19). The end-tidal carbon dioxide is the highest concentration at the end of exhalation. $ETCO_2$ monitoring is used in the clinical setting as a noninvasive indirect method of measuring $Paco_2$. In a normal person, $ETCO_2$ is 30–43 mm Hg, typically 4 to 6 mm Hg below $Paco_2$.



■ **FIGURE 10–19** Normal capnogram pattern divided into phases. Phase I, initial exhalation phase representing anatomical dead space; Phase II, rapid increase in CO_2 representing mixture of dead space and alveolar CO_2; Phase III, alveolar plateau representing alveolar CO_2; Phase IV, inspiratory phase.

Reproduced by permission of Respironics, Inc.

Invasive Blood Gas Monitoring

The arterial catheter (commonly called an "arterial line" or "art line") is an invasive means of monitoring a patient's hemodynamic status (e.g., blood pressure, mean arterial pressure, heart rate) as well as pulmonary gas exchange status. Arterial catheters are most commonly inserted into a radial artery but can also be inserted into a femoral or other artery. A major advantage of drawing blood, including arterial blood gases, from an indwelling arterial line is that frequent samples can be obtained without causing additional trauma and pain to the patient from repeated needle sticks.

Section Eight Review

1. What is pulse oximetry used to measure?
   A. Mixed venous saturation
   B. Transcutaneous oxygen saturation
   C. Venous oxygen capillary hemoglobin saturation
   D. Arterial oxygen capillary hemoglobin saturation
2. Which conditions impair the accuracy of pulse oximetry? (Select all that apply.)
   A. Pulmonary embolism
   B. Excessive movement
   C. Vasodilation
   D. Hypothermia
   E. Improper sensor placement
3. $ETCO_2$ is an indicator of which alveolar factor?
   A. Acid–base state
   B. Compensation
   C. Oxygenation
   D. Ventilation
4. Colorimetric capnography uses what measure to estimate $ETCO_2$?
   A. pH
   B. $PaCO_2$
   C. Inhaled CO_2
   D. HCO_3

Answers: 1. D, 2. (B, D, E), 3. D, 4. A

Clinical Reasoning Checkpoint

RM, a 45-year-old construction worker, is brought to the emergency department with complaints of severe shortness of breath and a productive cough that is keeping him up during the night. His medical history is positive for chronic bronchitis and hypertension. He has smoked one pack of cigarettes a day for the past 35 years. He is married and has three adult children. He was diagnosed with emphysema several years ago. During auscultation, you hear rhonchi, particularly evident in his right lung fields. His temperature is currently 100.4°F (38°C). He is tentatively diagnosed with bacterial pneumonia.

1. RM's emphysema disease state alters the surface area of his lungs in which way?
2. RM has developed consolidations in his alveoli from pneumonia. (a) Describe the type of pulmonary shunt this creates; and (b) explain how this will affect his receiving oxygen therapy.

Clinical Update: RM has an arterial blood gas drawn on room air. The results are: pH 7.28, $PaCO_2$ 53, PaO_2 56 mm Hg, HCO_3 36 mEq/L, and SaO_2 92. He has just had a portable chest x-ray done. The results show cor pulmonale.

3. Interpret his ABG, including degree of compensation.
4. What is his P/F ratio at this time and what is its significance?
5. RM asks you to explain what cor pulmonale is. What will you tell him?

Supplemental ABG Exercises

Interpret the acid–base status as normal, metabolic or respiratory, alkalosis or acidosis. Indicate the state of compensation as uncompensated (acute state), partially compensated, or compensated (chronic state). Indicate the oxygenation status as adequate or inadequate, when indicated.

1. pH 7.58, $Paco_2$ 38 mm Hg, HCO_3 30 mEq/L
   Interpretation:
   Compensation:
2. pH 7.20, $Paco_2$ 60 mm Hg, HCO_3 26 mEq/L
   Interpretation:
   Compensation:
3. pH 7.39, $Paco_2$ 43 mm Hg, HCO_3 24 mEq/L
   Interpretation:
   Compensation:
4. pH 7.32, $Paco_2$ 60 mm Hg, HCO_3 30 mEq/L
   Interpretation:
   Compensation:
5. pH 7.5, $Paco_2$ 50 mm Hg, HCO_3 38 mEq/L
   Interpretation:
   Compensation:
6. pH 7.45, $Paco_2$ 30 mm Hg, HCO_3 20 mEq/L
   Interpretation:
   Compensation:
7. pH 7.40, $Paco_2$ 40 mm Hg, HCO_3 24 mEq/L
   Interpretation:
   Compensation:
8. pH 7.37, $Paco_2$ 48 mm Hg, HCO_3 29 mEq/L, Pao_2 80 mm Hg, Sao_2 95%
   Acid–base state:
   Oxygenation status:
9. pH 7.48, $Paco_2$ 30 mm Hg, HCO_3 24 mEq/L, Pao_2 90 mm Hg, Sao_2 98%
   Acid–base state:
   Oxygenation status:
10. pH 7.48, $Paco_2$ 33 mm Hg, HCO_3 25 mEq/L, Pao_2 68 mm Hg, Sao_2 98%
    Acid–base state:
    Oxygenation status:
11. pH 7.38, $Paco_2$ 38 mm Hg, HCO_3 24 mEq/L, Pao_2 269 mm Hg, Sao_2 100%
    Acid–base state:
    Oxygenation status:
12. pH 7.17, $Paco_2$ 18 mm Hg, HCO_3 7 mEq/L, Pao_2 100 mm Hg, Sao_2 99%
    Acid–base state:
    Oxygenation status:

Answers to the Clinical Reasoning Checkpoint questions can be found in the Wagner Student Resources at www.pearsonglobaleditions.com/wagner.

Pearson Nursing Student Resources Find additional review materials at: **www.pearsonglobaleditions.com/wagner**

Posttest

1) A patient has developed a pulmonary problem that has resulted in decreased lung compliance. How will this affect the patient's respiratory system?
   1. It will increase the patient's work of breathing.
   2. It will increase the patient's tidal volume.
   3. It will decrease the patient's carbon dioxide level.
   4. It will decrease the patient's overall oxygen consumption.
2) A patient who has developed right middle-lobe pneumonia will experience decreased ventilation in the affected lung areas for which reasons? (Select all that apply.)
   1. Gas follows the path of least resistance.
   2. The pressure gradient is abnormal.
   3. Decreased perfusion causes decreased ventilation.
   4. Gas moves from an area of low pressure to an area of high pressure.
   5. The consolidation in the tissues will increase the pressure.
3) A patient with pneumonia develops what is believed to be an absolute pulmonary shunt. Oxygen therapy has been initiated per venti-mask. The nurse would expect which effect on the patient's hypoxemia?
   1. It will worsen.
   2. It will be unchanged.
   3. It will initially improve, then worsen again.
   4. It will be relieved.
4) A patient is diagnosed with DKA after being admitted to the hospital with a serum glucose of 650 mg/dL and positive serum ketones. Blood gases are: pH 7.25, $PaCO_2$ 36 mm Hg, HCO_3 14 mEq/L. This pH is most likely a result of which acid–base disturbance?
   1. Respiratory acidosis
   2. Metabolic acidosis
   3. Metabolic alkalosis
   4. Respiratory alkalosis

5) A patient has the following ABG results: pH 7.50; $PaCO_2$ 30 mm Hg; HCO_3 20 mEq/L, PaO_2 88 mm Hg, SaO_2 98%. How would the nurse interpret these results?
 1. Compensated respiratory acidosis
 2. Compensated metabolic acidosis
 3. Partially compensated respiratory alkalosis
 4. Partially compensated metabolic acidosis

6) A patient is admitted to the hospital with complaints of severe chest pain and dyspnea. The patient has an oral temperature of 38.3°C (101°F). Why is it important for the nurse to obtain a nutritional history from this patient? (Select all that apply.)
 1. High-carbohydrate intake weakens respiratory muscles.
 2. Poor nutritional status increases susceptibility to infection.
 3. Hypoglycemia weakens respiratory muscles.
 4. Vitamin C intake above the recommend daily amount causes oxidative changes in lung tissue.
 5. High-carbohydrate diets increase carbon dioxide levels.

7) Pulmonary function tests are performed on a patient diagnosed with right middle-lobe pneumonia. The patient's tidal volume and vital capacity are both below normal. The nurse would plan care based on which interpretation of these results?
 1. The patient has respiratory muscle fatigue.
 2. The patient has loss of pulmonary surfactant.
 3. The patient is hyperventilating.
 4. The patient has increasing atelectasis.

8) A patient has been in the ICU intubated for 1 week. $ETCO_2$ is attached to the patient's mechanical ventilator circuit to assess for which development?
 1. Oxygenation failure
 2. Early changes in ventilation
 3. Ventilatory dependency
 4. Early tissue metabolic changes

9) A patient comes to the emergency department complaining of shortness of breath and chest pain. The ABG results are: pH 7.45, $PaCO_2$ 35 mm Hg, PaO_2 60 mm Hg, HCO_3 24 mEq/L. What should be the nurse's first intervention?
 1. Place the patient on oxygen.
 2. Set up for intubation.
 3. Administer sodium bicarbonate.
 4. No intervention is necessary.

10) A patient is admitted to the emergency department with complaints of shortness of breath, cough, and fever. Which clinical manifestations would the nurse interpret as indicating early respiratory distress? (Select all that apply.)
 1. Tachycardia
 2. Cyanosis
 3. Agitation
 4. Confusion
 5. Increased respiratory rate

Answers to Posttest questions can be found in the Wagner Student Resources at www.pearsonglobaleditions.com/wagner.

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11

Alterations in Pulmonary Function

LEARNING OUTCOMES

Following completion of this chapter, the learner will be able to

1. Explain the basic differences between restrictive and obstructive pulmonary diseases.
2. Discuss the pathophysiologic basis of respiratory failure.
3. Describe acute respiratory distress syndrome (ARDS).
4. Explain the types, pathophysiology, and management of acute pulmonary embolism.
5. Discuss the types, pathophysiology, and management of acute bacterial and viral pneumonias.
6. Describe the principles and management of patients undergoing thoracic surgery and chest drainage.
7. Implement a general plan of care for a patient with an acute alteration in respiratory function.

High-acuity patients may be admitted in acute pulmonary distress, or severe pulmonary disorders may develop after admission. It is critical that nurses working in high-acuity environments be able to rapidly recognize acute pulmonary diseases and complications and their treatments. It is suggested that Chapter 10, Determinants and Assessment of Pulmonary Function be read prior to this chapter for important foundational information that will enhance the reader's understanding of the material in this chapter.

SECTION ONE: Review of Restrictive and Obstructive Pulmonary Disorders

Pulmonary diseases may be divided into acute and chronic problems. Acute problems have a rapid onset, are episodic, and frequently are confined to the lungs. In contrast, chronic problems usually have a slow, often insidious onset, and the pulmonary impairment either does not change or slowly worsens over an extended period. Chronic pulmonary problems generally involve other organs as part of the disease process. Patients with chronic pulmonary problems, such as emphysema, may develop an acute problem (e.g., pneumonia) that may further stress their pulmonary status.

Pulmonary diseases may be divided further into problems of inflow of air (restrictive) and outflow of air (obstructive). By being able to differentiate between obstructive and restrictive pulmonary diseases, the nurse can apply appropriate nursing diagnoses regardless of the medical diagnosis of the specific pulmonary disease process.

Restrictive Pulmonary Disorders

Restrictive disorders are associated with decreased lung compliance (C_L), the relative stiffness of the lungs, and decreased lung expansion. They may be caused by internal problems, such as a decrease in the number of functioning alveoli (e.g., atelectasis or pneumonia), a loss of lung tissue (e.g., pneumonectomy or lung tumors), or by external problems (e.g., chest burns or morbid obesity). Table 11–1 provides a more complete listing of restrictive disorders.

Restrictive disorders are problems of volume (the amount of air, measured in mL or L, that flows in and out of the lungs) rather than airflow (the rate or speed at which air moves into or out of the lungs). In other words, the volume of air that is inhaled can be exhaled at a normal rate of flow. The patient with a restrictive disorder will have a reduced tidal volume (V_T) and total lung capacity (TLC). Air cannot move into the alveoli as readily as it should because of limited expansion (decreased

TABLE 11–1 Common Restrictive Pulmonary Disorders

External Problems	Internal (Parenchymal) Problems
Obesity	Pneumonia
Neuromuscular diseases:	Atelectasis
Myasthenia gravis	Heart failure
Muscular dystrophy	Pulmonary edema
Guillain–Barré syndrome	Pulmonary fibrosis
Spinal cord trauma	Pulmonary tumors
Chest wall disorders:	Pneumothorax
Extensive chest burns	Asbestosis
Scoliosis	
Flail chest	

lung compliance), which can lead to alveolar hypoventilation. Hypoxemia will result if alveolar oxygen diffuses into the blood at a faster rate than it is replaced by ventilation. When this occurs, the Pao_2 falls at approximately the same rate as the $Paco_2$ rises, assuming that diffusion is normal.

Restrictive pulmonary problems often disturb the relationship of ventilation to perfusion ($\dot{V}/\dot{Q}$ ratio). In mild-to-moderate restrictive disease, the $\dot{V}/\dot{Q}$ ratio may stay normal because both ventilation and perfusion may be fairly equally disturbed. In many acute restrictive diseases, perfusion becomes diminished because of edema that results from an inflammatory process. Perfusion can also become reduced by compression or blockage of the pulmonary vasculature. In severe disease, a low $\dot{V}/\dot{Q}$ ratio may develop because ventilation is greatly diminished, whereas perfusion may be fairly normal or moderately disturbed. A low $\dot{V}/\dot{Q}$ ratio is associated with hypoxemia with a decreasing pH and increasing $Paco_2$. Box 11–1 lists the typical signs and symptoms associated with restrictive pulmonary disorders.

Obstructive Pulmonary Disorders

Chronic obstructive pulmonary disease (COPD) is the term commonly applied in the clinical setting to pulmonary disorders that hinder expiratory airflow. The more accurate and preferred term for these disorders, however, is *chronic airflow limitation.* Currently, these two terms are often used interchangeably. Some of the major obstructive disorders include

- Emphysema
- Chronic bronchitis
- Asthma
- Cystic fibrosis

In obstructive pulmonary disorders, air is able to flow into the lungs but then becomes trapped. The inability to exhale rapidly causes a prolongation of expiratory time. If expiratory time becomes significantly prolonged, the alveoli are unable to empty before the person inhales again, trapping CO_2 within them. Expiratory times are measured using **forced expiratory volume (FEV)** testing, which is a measure of dynamic lung function. FEV testing determines how rapidly a person can forcefully exhale air after a maximal inhalation.

Obstructive problems may be caused by airway narrowing, such as bronchospasm, bronchoconstriction, and edema; or by airway obstruction, such as is seen with pooling of secretions or destruction of bronchioles and alveoli. Obstructive disorders are associated with increased lung compliance (hyperinflated lungs) accompanied by a loss of elastic recoil. The $\dot{V}/\dot{Q}$ ratio may be disturbed with this group of disorders. In disease processes that do not destroy alveoli, such as chronic bronchitis, the $\dot{V}/\dot{Q}$ ratio may be low (i.e., ventilation is reduced, whereas perfusion remains normal). If lung tissue is actually destroyed, such as occurs with emphysema, the $\dot{V}/\dot{Q}$ ratio may remain normal because both ventilation and perfusion are equally impaired. A normal $\dot{V}/\dot{Q}$ ratio does not necessarily indicate healthy lungs. It indicates only that a balance exists between ventilation and blood flow. Box 11–2 lists the typical clinical manifestations associated with obstructive pulmonary disorders.

Restrictive and obstructive diseases differ in their effect on lung volume, air flow, pathophysiology, blood gas disturbances, and physical assessment. Table 11–2 compares these two disease processes.

Status Asthmaticus Asthma differs from the other obstructive pulmonary diseases in that the airflow obstruction

BOX 11–1 Clinical Manifestations of Restrictive Pulmonary Disorders

- Increased respiratory rate
- Decreased tidal volume (VT)
- Normal to decreased Pao_2
- Shortness of breath
- Cough
- Chest pain or discomfort
- Fatigue
- History of weight loss

BOX 11–2 Clinical Manifestations of Obstructive Pulmonary Disorders

- Mucus hypersecretion (except with pure emphysema)
- Wheezes, rhonchi
- Dyspnea (episodic or progressive)
- Diminished breath and heart sounds
- Barrel chest (increased AP diameter)
- Progressive hypercapnia and respiratory acidosis
- Progressive or episodic hypoxemia (particularly in later stages)
- Cor pulmonale
- Accessory muscle use
- Increased expiratory time (expiration time longer than inspiration time)
- Pulmonary function tests (PFTs): Normal to increased TLC, increased FRC, decreased FEV, decreased VC

TLC=total lung capacity; FRC=functional residual capacity; FEV=forced expiratory volume; VC=vital capacity