Therapeutic Exercise
Foundations and Techniques

FIFTH EDITION

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Cardiovascular and pulmonary physical therapy is a multifaceted area of professional practice that deals with the management of patients of all ages with acute or chronic, primary or secondary cardiovascular and pulmonary disorders. Although the cardiovascular and pulmonary systems are inherently linked as they interface with all other body systems, the focus of this chapter is on examination procedures and therapeutic interventions used for the management of patients with pulmonary dysfunction. In particular, exercise interventions and manual techniques that enhance ventilation and airway clearance are presented.

The goals of cardiovascular and pulmonary physical therapy for patients with respiratory dysfunction are to:

- Prevent airway obstruction and accumulation of secretions that interfere with normal respiration/oxygen transport.
- Improve airway clearance, cough effectiveness, and ventilation through mobilization and drainage of secretions.
- Improve endurance, general exercise tolerance, and overall well-being.
- Reduce energy costs during respiration through breathing retraining.
- Prevent or correct postural deformities associated with pulmonary or extrapulmonary disorders.
- Maintain or improve chest mobility.
All of these goals are aimed at improving a patient’s overall ability to meet necessary and desired functional demands.

Treatment settings vary widely, from intensive care or postsurgical care units and extended care/subacute rehabilitation facilities to outpatient pulmonary centers and the home setting.

Review of Respiratory Structure and Function

Respiration is a general term used to describe gas exchange within the body and can be categorized as either external respiration or internal respiration. Basic terms are described here but an in-depth discussion of respiratory physiology, including diffusion and perfusion, goes well beyond the scope or purpose of this chapter. The reader is referred to several references for further study.11,22,34,59,61

External respiration describes the exchange of gas at the alveolar-capillary membrane and the pulmonary capillaries. When a person inhales and oxygen is delivered to the alveoli via the tracheobronchial tree, oxygen diffuses through the alveolar wall and interstitial space and into the bloodstream through the pulmonary capillary walls. The opposite occurs with carbon dioxide transport.

Internal respiration describes the exchange of gas between the pulmonary capillaries and the cells of the surrounding tissues. Internal respiration occurs when oxygen in arterial blood diffuses from red blood cells into tissues requiring oxygen for function. The reverse occurs with carbon dioxide transport.

Ventilation, as it refers to the respiratory system, is the mass exchange of air to and from the body during inspiration and expiration. This cyclic process requires coordinated ventilatory muscle activity, rib cage movements, and appropriate structure and function of the upper and lower respiratory tracts.8,22,34,59,61

Thorax and Chest Wall: Structure and Function

The main functions of the thoracic cage, also referred to as the chest wall, are to protect the internal organs of respiration, circulation, and digestion and to participate in ventilation of the lungs.58 The thoracic cage provides the site of attachment for the muscles of ventilation to mechanically enlarge the thorax for inspiration or to compress the thorax for expiration.68 It is also the site of attachment of extremity muscles, which function during lifting, pulling, or pushing activities. These activities usually are carried out in conjunction with inspiratory effort.

Along the posterior aspect of the thorax, the dorsal portions of the ribs articulate with the 12 thoracic vertebrae at the costotransverse and costovertebral joints. Along the anterior aspect of the thoracic cage, the first to seventh ribs articulate directly with the sternum via the costal cartilage. The eighth to tenth ribs have cartilaginous attachments to the rib above, whereas the eleventh and twelfth are floating ribs (Fig. 25.1).68

Muscles of Ventilation

Multiple muscles attaching to the thoracic cage have an impact on the movement of air in and out of the lungs during either the inspiratory or expiratory phases of breathing.8,11,68 Box 25.1 lists the muscles of ventilation.9

Ventilatory muscles, also referred to as respiratory muscles, are classified as primary or accessory.56,68 The primary muscles of ventilation are recruited during quiet (tidal) breathing, whereas the accessory muscles of ventilation are only recruited during deep, forced, or labored breathing. During quiet inspiration the diaphragm, scalenes, and parasternals are activated.56,68 In contrast, no primary ventilatory muscles contract during resting expiration. During deep or forced breathing different accessory muscles of ventilation are recruited, depending on whether inspiration or expiration is occurring, as noted in Box 25.1.

Inspiration

Diaphragm. The diaphragm, the major muscle of inspiration, is innervated by the phrenic nerve (C3, C4, C5). During relaxed inspiration it is the primary muscle responsible for movement of air, and under these quiet conditions it performs about 70% to 80% of the work of breathing.56 As the diaphragm contracts, it moves caudally from its dome-shaped position at rest to increase the capacity of the thoracic cage.

Scalenes. The scalenes, which insert proximally on the transverse processes of the lower five cervical vertebrae and distally on the upper surface of the first two ribs, also
Inspection
• Primary muscles: diaphragm, scalenes, parasternals
• Accessory muscles: sternocleidomastoids, upper trapezius, pectoralis major and minor, subclavus, and possibly the external intercostals

Expiration
• Primary muscles: none active during tidal (resting) expiration
• Accessory muscles: abdominals including the rectus abdominis, transversus abdominis, and internal and external obliques; pectoralis major; and possibly the internal intercostals

Expiration is a passive process when a person is at rest. When the diaphragm relaxes after a contraction, the diaphragm rises and the ribs drop. The elastic recoil of tissues decreases the intrathoracic area and increases intrathoracic pressure, which causes exhalation. During active expiration, which can be controlled, forced, or prolonged, several accessory muscles groups are active.9,56,68

Abdominals. The rectus abdominis, the internal and external obliques, and the transversus abdominis contract to force down the thoracic cage and force the abdominal contents superiorly into the diaphragm. When the abdominals contract, the intrathoracic pressure increases and air is forced out of the lungs. A strong contraction of the abdominals also is necessary for a strong cough. The abdominals are innervated by spinal cord levels T10 to T12.

Other accessory muscles of expiration include the pectoralis major muscles (when the distal insertion is inferior to the clavicle and the arm is fixed in position), the quadratus lumborum, because of its attachment to the twelfth rib, which enables it to act to stabilize the diaphragm during phonation, and possibly the internal intercostals, which may act to depress the rib cage.9,56,68

Mechanics of Ventilation

Movements of the Thorax During Ventilation
Each rib has its own pattern of movement, but generalizations can be made. The ribs attach anteriorly to the sternum (except ribs 11 and 12) and posteriorly to the vertebral bodies, disks, and transverse processes, making a closed kinematic chain. The thorax enlarges in all three planes of movement during inspiration.8,11,56,68

Increase in the AP dimension. There is a forward and upward movement of the sternum and upper ribs, described as a pump-handle motion. The thoracic spine extends (straightens), enabling greater excursion of the sternum.

Increase in the transverse (lateral) dimension. There is an elevation and outward turning of the lateral (midshaft) portions of the ribs, described as a bucket handle motion. The lower ribs (8–10), which are not attached directly to the sternum, also flare or open outward, increasing the subcostal angle. This is described as caliper motion. The angle at the costochondral junction also increases, making the rib segments longer during inspiration.

Increase in vertical dimension. The central tendon of the diaphragm descends as the muscle contracts. This is described as a piston action. Elevation of the ribs increases the vertical dimension of the thorax and improves the effectiveness of the diaphragm. At the end of inspiration, the muscles relax and elastic recoil causes the diaphragm to move superiorly. The ribs return to their resting position.
Movement of Air
As noted previously, ventilation is the mass exchange of gases to and from the body. During inspiration, as the thorax enlarges, the pressure inside the lungs (alveolar pressure) becomes lower than the atmospheric pressure, and air rushes into the lungs. At the end of inspiration, the muscles relax, and the elastic recoil of the lungs pushes the air out, resulting in expiration.

**NOTE:** Breathing exercises, a common intervention for the management of patients with cardiopulmonary, neuromuscular, and musculoskeletal conditions, are designed to affect the movement of air to and from the lungs.¹ ¹,²,²⁸,⁴⁸,⁵⁶

Compliance
Compliance refers to the distensibility of tissue or how easily the lungs inflate during inspiration. With regard to ventilation, it relates to how easily the lungs inflate or the chest wall expands during inspiration.²²,⁵⁹,⁶¹ Normal lungs are highly distensible (compliant), but compliance changes with age and the presence of disease. During the normal aging process lung tissue becomes more compliant. Diseases of the pulmonary system that, for example, cause fibrosis of tissues (alveolar or pleural) make the lungs rigid (i.e., less compliant), whereas emphysema, one of the chronic obstructive diseases, makes lung tissue more compliant to pressures.²²,⁵⁹,⁶¹

Airway Resistance
The amount of resistance to the flow of air through the Airways depends on a number of factors.²²,⁵⁹,⁶¹ The bifurcation and branching of Airways is a source of airway resistance. The size (diameter) of the lumen of each Airways also influences resistance. The diameter of the lumen can be decreased by mucus or edema in the Airways, contraction of smooth muscles, and the degree of elasticity or distensibility of the lung parenchyma.

Normally, the Airways widen during inspiration and narrow during expiration. As the diameter of the Airways decreases, the resistance to airflow increases. With diseases that cause bronchospasm (asthma) or increased mucus production (chronic bronchitis), Airways resistance is even greater than normal, particularly during expiration.

Flow Rates
Flow rates indicate measurements of the amount of air moved in or out of the Airways over a period of time. Flow rates, which are related to airflow resistance, reflect the ease with which ventilation occurs.²²,⁵⁹,⁶¹ Expiratory flow rate is determined by the volume of air exhaled divided by the amount of time it takes for the volume of gas to be exhaled.²⁷

Flow rates are altered as the result of diseases that affect the respiratory tree and chest wall. For example, with chronic obstructive pulmonary disease, the expiratory flow rate is decreased in comparison to normal. That is, it takes a longer than the normal amount of time to exhale a specific volume of air.

Anatomy and Function of the Respiratory Tracts

Upper Respiratory Tract
The structures of the upper respiratory tract are the nasal cavity, pharynx, and larynx.¹¹,⁵⁸,⁶⁶,⁶⁹ As air is brought into the body, the nasal cavity and pharynx filter and remove particles in the air and begin to humidify and warm it to body temperature. The mucosal lining of these structures has cells that secrete mucus and cells that are ciliated. Cilia and mucus trap particles; a sneeze removes large particles.

With illness and elevated body temperature, the mucous membrane tends to dry out, so the body secretes more mucus. This mucus dries out, and a cycle begins. The action of the cilia is inhibited by drying of mucus. The patient tends to breathe by mouth, which decreases the humidification of mucus and increases its viscosity.

The larynx, which extends from C3 to C6, controls airflow; and when it contracts rapidly, the epiglottis prevents food, liquids, or foreign objects from entering the Airways.⁴⁷

Lower Respiratory Tract
The lower respiratory tract is composed of conducting Airways of the tracheobronchial tree and the terminal respiratory units. There are approximately 23 generations (branchings) of the structures within the tracheobronchial tree, which extends from the trachea to the terminal respiratory units of the lungs. The structures and branchings of the lower respiratory tract are summarized in Box 25.2.¹¹,⁵⁸,⁶⁶,⁶⁹

The initial branchings of the tracheobronchial tree are depicted in Figure 25.2. The first 16 Airways branchings of the lower respiratory tract primarily conduct air, whereas the last 6 Airways Airways that end (in the mature lung) in approximately 300 million alveoli.⁶⁹ The diameter of the Airways becomes increasingly smaller with each successive generation of the tracheobronchial tree.

**Trachea.** The trachea is an oval, flexible tube supported by semicircular rings of cartilage. It extends from C6 in an oblique, downward direction to the sternal angle level of rib 2 and T6, at which point it bifurcates. The posterior wall is smooth muscle, and it contains an equal number of ciliated epithelial cells and mucus-containing goblet cells.

**BOX 25.2 Structures and Branchings of the Lower Respiratory Tract**
- Trachea
- Mainstem bronchi: 2
- Lobar bronchi: 5
- Segmental bronchi: 18
- Bronchioles: subsegmental, terminal, and respiratory
- Alveolar ducts and sacs
Mainstem bronchi. The trachea branches into two main-stream bronchi: the right, which is directed almost vertically, and the left, which is directed more obliquely.

Lobar bronchi. The two mainstem bronchi then divide into five lobar bronchi: three on the right and two on the left. Mainstem and lobar bronchi have a great amount of cartilage, which helps maintain airway patency.

Segmental bronchi. Each of the lobar bronchi divide into two or more segmental bronchi: 10 on the right and 8 on the left. Segmental bronchi have scattered cartilage, smooth muscle, elastic fibers, and a capillary network. The mainstem, lobar, and segmental bronchi have a mucous membrane essentially the same as the trachea.

Bronchioles. Segmental bronchi divide into subsegmental bronchi and bronchioles, which have less and less cartilage and ciliated epithelial cells. These bronchioles divide into the terminal bronchioles, which are distal to the last cartilage of the tracheobronchial tree. Terminal bronchioles contain no ciliated cells. Terminal bronchioles divide into respiratory bronchioles and provide a transitional zone between the bronchioles and alveoli.

Alveoli. The respiratory bronchioles divide into alveolar ducts and alveolar sacs (Fig. 25.3). One duct may supply several sacs. The ducts contain smooth muscle, which narrows the lumen of the duct with contraction. The alveoli are located in the periphery of the alveolar ducts and sacs and are in contact with capillaries (alveolar-arterial membrane). Gas exchange occurs here.

Summary of Function of the Upper and Lower Respiratory Tracts
The upper and lower respiratory tracts, as a unit, serve the following functions. They:

- Conduct air to and from the alveolar system for gas exchange
- Assist with humidification and trap small particles to clean the air with the mucosal lining
- Warm the air by the vascular supply
- Move mucus upward with the cilia
- Elicit the cough reflex to clear the larger airways

The Lungs and Pleurae
The lungs and pleurae are made up of the following components. The right lung has three lobes—the upper, middle, and lower—and 10 bronchopulmonary segments. The left lung has two true lobes—the upper and lower—and a slip of lung called the lingula, which is not considered a “true” lobe of the lungs. The left lung has eight bronchopulmonary segments. The lobes of the lungs are depicted in Figure 25.4.
Each lung is covered in pleura, a serous membrane known as the visceral pleura. This membrane adheres to all surfaces of each lung. The parietal pleura lines the inside of the thoracic wall. The parietal pleura is sensitive to pain, but the visceral pleura appears to be insensitive. A negative pressure in the minute space between the pleurae serves to keep the lungs inflated. Pleural fluid is found between the pleurae and lubricates the pleurae as they slide on each other during ventilation.

**Lung Volumes and Capacities**

Pulmonary function tests that measure lung volumes and capacities are performed to evaluate the mechanical function of the lungs (Fig. 25.5). Lung volumes and capacities are related to a person’s age, weight, sex, and body position and are altered by disease. Two or more lung volumes, when combined, are described as a capacity. A basic understanding of these measurements and what the values reflect is useful for a therapist treating patients with pulmonary dysfunction.

**Expiratory Reserve Volume**

Expiratory reserve volume (ERV) is the amount of air a person can exhale after a normal resting expiration (approximately 1000 mL).

**Residual Volume**

Residual volume (RV) is the amount of air left in the lungs after a maximum expiration (approximately 1500 mL). RV increases with age and with restrictive and obstructive pulmonary diseases.

**Inspiratory Capacity**

Inspiratory capacity (IC) is the maximum amount of air a person can breathe in after a resting expiration (approximately 3500 mL).

**Functional Residual Capacity**

Functional residual capacity (FRC) is the amount of air remaining in the lungs after a resting (tidal) expiration (approximately 2500 mL). It is the sum of the ERV and RV. FRC represents the point during ventilation at which the forces that expand the thoracic wall are in balance with the forces that tend to collapse the lungs.

**Vital Capacity**

Vital capacity (VC) is the sum of the TV, IRV, and ERV. It is measured by a maximum inspiration followed by a maximum expiration (approximately 4500 mL). Vital capacity decreases with age and is less in the supine position than in an erect posture (sitting or standing). VC decreases in the presence of restrictive and obstructive diseases.

**Total Lung Capacity**

Total lung capacity (TLC) is the total amount of air contained in the lungs after a maximum inspiration. TLC can be subdivided into four volumes: tidal volume, inspiratory reserve volume, expiratory reserve volume, and residual volume. The vital capacity plus the residual volume equal the TLC, which is approximately 6000 mL in a healthy, young adult.

**Tidal Volume**

The amount of air exchanged during a relaxed inspiration followed by a relaxed expiration is called the tidal volume (TV). In a healthy, young adult, TV is approximately 500 mL per inspiration. Approximately 350 mL of the tidal volume reaches the alveoli and participates in gas exchange (respiration).

**Inspiratory Reserve Volume**

Inspiratory reserve volume (IRV) is the amount of air a person can breathe in after a resting inspiration (approximately 3000 mL).

**Box 25.3 Purpose of the Examination**

- Determine a patient’s primary and secondary respiratory and ventilatory impairments and how they limit physical function.
- Determine the adequacy of the ventilatory pump and the oxygen uptake/carbon dioxide elimination mechanisms to meet the oxygen demands at rest and during functional activities.
- Ascertain a patient’s suitability for participation in a pulmonary rehabilitation program.
- Develop an appropriate level intervention plan for the patient.
- Establish a baseline to measure a patient’s progress and the effectiveness of the treatment.
- Determine when to discontinue specific interventions and implement a home program as a basis for self-management.
Components of the Examination

A comprehensive examination of a patient with known or suspected dysfunction related to primary and secondary pulmonary or chest disorders has many elements. The examination procedures described in this section are those often used by a therapist during an initial evaluation to establish a therapy-related diagnosis or during subsequent assessments for modification of therapeutic interventions. Additional examination procedures not described in this section but integral to the management of a patient with pulmonary dysfunction are radiography, evaluation of blood gases, tomography, bronchoscopy, and hematological tests.

History and Systems Review

The examination process begins with a patient’s history including an interview with the patient and sometimes family members if they are available. During the interview a therapist can identify a patient’s chief complaints and why he or she is seeking treatment. In preparation for the interview, the medical history and any medical diagnoses are obtained from the patient’s medical record, if available, or more generally, from the patient or family. Relevant occupational and social history are obtained; particularly important are on-the-job physical demands, the environment of the workplace, and social habits that affect a person’s well-being, such as tobacco or alcohol use. Assessment of the home or family environment might include a patient’s family responsibilities, the housing situation, and available family support systems. A brief systems review should follow the history.

General Appearance of the Patient

Table 25.1 describes the type of information that can be obtained by visual inspection of a patient and the possible implications of these observations. Many of these findings can be noted during the course of the history or during the systems review.

Analysis of Chest Shape and Dimensions

Symmetry of the chest and trunk. Observe anteriorly, posteriorly, and laterally; the thoracic cage should be symmetrical.

Mobility of the trunk. Check active movements in all directions and identify any restricted spinal motions, particularly in the thoracic spine.

Shape and dimensions of the chest. The anteroposterior (AP) and lateral dimensions are usually 1:2. Common chest deformities include:

- **Barrel chest.** The circumference of the upper chest appears larger than that of the lower chest. The sternum appears prominent, and the AP diameter of the chest is greater than normal. Many patients with chronic obstructive pulmonary disorders, who are usually upper chest breathers, develop a barrel chest.

- **Pectus excavatum (funnel breast).** The lower part of the sternum is depressed and the lower ribs flare out. Patients with this deformity are diaphragmatic breathers;

<table>
<thead>
<tr>
<th>General Appearance</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of awareness (level of consciousness): alert, responsive, or cooperative</td>
<td>• Respiratory acidosis, hypercarbia (increased Pco₂ level),</td>
</tr>
<tr>
<td>or cooperative versus lethargic, disoriented, or inattentive</td>
<td>or hypoxia (decreased Po₂ level) can alter level of consciousness</td>
</tr>
<tr>
<td>Body type: normal, obese, or cachectic</td>
<td>• May reflect intolerance to exercise</td>
</tr>
<tr>
<td>Color: cyanosis (bluish appearance) peripherally (nailbeds) or centrally (lips)</td>
<td>• Peripheral cyanosis may indicate low cardiac output;</td>
</tr>
<tr>
<td>Facial signs or expressions: focused or dilated pupils, nasal flaring, sweating,</td>
<td>central cyanosis may indicate inadequate gas exchange</td>
</tr>
<tr>
<td>or distressed appearance</td>
<td>in the lungs</td>
</tr>
<tr>
<td>Jugular vein engorgement: visualization of the jugular venous pulse with the patient</td>
<td>• Signs of respiratory distress, fatigue, or pulmonary or muscularkeletal pain</td>
</tr>
<tr>
<td>supine and the head and neck on pillows at a 45° angle</td>
<td>Bilateral distention associated with congestive heart</td>
</tr>
<tr>
<td>Hypertrophy of or use at rest of accessory muscles of ventilation: SCM, upper</td>
<td>failure/right-sided heart failure</td>
</tr>
<tr>
<td>trapezius</td>
<td>• Seen in patients with early chronic lung disease or weakness of the diaphragm</td>
</tr>
<tr>
<td>Supravclicular or intercostal retractions occurring with inspiration</td>
<td>• Seen in patients with labored breathing</td>
</tr>
<tr>
<td>Use of pursed lip breathing (usually with expiration)</td>
<td>• Indicates difficulty with expiration; often seen in patients with COPD</td>
</tr>
<tr>
<td>Clubbing of digits: loss of angle between the nail bed and DIP joint</td>
<td>• May be linked to perfusion</td>
</tr>
<tr>
<td>Peripheral edema</td>
<td>• Sign of right ventricular failure or lymphatic dysfunction</td>
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excessive abdominal protrusion and little upper chest movement occur during breathing. **Pectus carinatum (pigeon breast).** The sternum is prominent and protrudes anteriorly.

**Posture or Preferred Positioning**

Identify a patient’s preferred sitting or standing posture. A patient who has difficulty breathing as the result of chronic lung disease often leans forward on hands or forearms to stabilize and elevate the shoulder girdle to assist with inspiration (Fig. 25.6). This position increases the effectiveness of the pectoralis and serratus anterior muscles to act as accessory muscles of inspiration by reverse action. It is also important to identify a patient’s preferred sleeping position. A patient with cardiopulmonary dysfunction often prefers to sleep in a head-up rather than a fully recumbent position. Assuming a horizontal position may result in shortness of breath.

The normal sequence of inspiration at rest is (1) the diaphragm contracts and descends and the abdomen (epigastric area) rises; (2) this is followed by lateral costal expansion as the ribs move up and out; and finally (3) the upper chest rises. The neck muscles that act as accessory muscles of inspiration should be inactive during relaxed inspiration.

To assess the breathing sequence, have the patient assume a comfortable position (semireclining or supine). Place your hands on the patient’s epigastric region and sternum to observe movements in these two areas.

A number of terms are used to describe abnormal breathing patterns and are defined in Box 25.4. 11,35,38,52

**Chest Mobility**

**Symmetry of chest movement.** Analysis of the symmetry of the moving chest during breathing gives the therapist information about the mobility of the thorax and indicates indirectly what areas of the lungs may or may not be responding.

**Procedure:** Place your hands on the patient’s chest and assess the excursion of each side of the thorax during inspiration and expiration. Each of the three lobar areas can be checked.11,35,38,52

- To check upper lobe expansion, face the patient; place the tips of your thumbs at the midsternal line at the sternal notch. Extend your fingers above the clavicles. Have the patient fully exhale and then inhale deeply.
- To check middle lobe expansion, continue to face the patient; place the tips of your thumbs at the xiphoid process and extend your fingers laterally around the ribs. Again, ask the patient to breathe in deeply (Fig. 25.7A).
- To check lower lobe expansion, place the tips of your thumbs along the patient’s back at the spinous processes (lower thoracic level) and extend your fingers around the ribs. Ask the patient to breathe in deeply (Fig. 25.7B).

In addition, note any postural deformities such as kyphosis and scoliosis and postural asymmetry from thoracic surgery, which could restrict chest movements and ventilation.

**Breathing Pattern**

Assess the rate, regularity, and location of ventilation at rest and with activity. A normal respiratory rate for a healthy adult is 12 to 20 breaths per minute. This is most accurately determined when a patient is unaware that his or her respiratory rate is being measured, as when taking the pulse rate. The normal ratio of inspiration to expiration at rest is 1:2 and with activity 1:1. A patient with chronic obstructive pulmonary disease (COPD) may have a ratio of 1:4 at rest, which reflects difficulty with the expiratory phase of breathing.

**BOX 25.4 Abnormal Breathing Patterns**

- **Dyspnea.** Distressed, labored breathing as the result of shortness of breath.
- **Tachypnea.** Rapid, shallow breathing; decreased tidal volume but increased rate; associated with restrictive or obstructive lung disease and use of accessory muscles of inspiration.
- **Bradypnea.** Slow rate with shallow or normal depth and regular rhythm; may be associated with drug overdose.
- **Hyperventilation.** Deep, rapid respiration; increased tidal volume and increased rate of respiration; regular rhythm.
- **Orthopnea.** Difficulty breathing in the supine position.
- **Apnea.** Cessation of breathing in the expiratory phase.
- **Apneusis.** Cessation of breathing in the inspiratory phase.
- **Cheyne-Stokes.** Cycles of gradually increasing tidal volumes followed by a series of gradually decreasing tidal volumes and then a period of apnea. This is sometimes seen in the patient with a severe head injury.
Chest wall pain of musculoskeletal origin often increases with deep inspiration. Ask the patient to take a deep breath and identify any painful areas of the chest wall. Your hands to identify any specific areas of pain potentially of musculoskeletal origin. Ask the patient to take a deep breath and identify any painful areas of the chest wall. Chest wall pain of musculoskeletal origin often increases with direct point pressure during palpation and during a deep inspiration.

Specific areas or points of pain over anterior, posterior, or lateral aspects of the chest wall can be identified with palpation. 

**Procedure:** Firmly press against the chest wall with your hands to identify any specific areas of pain potentially of musculoskeletal origin. Ask the patient to take a deep breath and identify any painful areas of the chest wall. Chest wall pain of musculoskeletal origin often increases with direct point pressure during palpation and during a deep inspiration.

**NOTE:** Pain in the anterior, posterior, or lateral region of the chest can be of musculoskeletal, pulmonary, or cardiac origin. Pain of pulmonary origin is usually localized to a region of the chest but also may be felt in the neck or shoulder region. Several pulmonary or cardiac conditions can mimic musculoskeletal pain, such as pulmonary embolism, pleurisy, pneumonia, pneumothorax, and pulmonary artery hypertension.

**Mediastinal shift.** The position of the trachea normally is oriented centrally in relation to the suprasternal notch indicating symmetry of the mediastinum. The position of the trachea shifts as the result of asymmetrical intrathoracic pressures or lung volumes. For example, if the patient has had a pneumonectomy (removal of a lung), the lung volume on the operated side decreases, and the trachea shifts toward that side. Conversely, if the patient has a hemothorax (blood in the thorax), intrathoracic pressure on the side of the hemothorax increases, and the mediastinum shifts away from the affected side of the chest.

**Procedure:** To identify a mediastinal shift, have the patient sit facing you with the head in midline and the neck slightly flexed to relax the sternocleidomastoid muscles. With your index finger, gently palpate the soft tissue space on either side of the trachea at the suprasternal notch. Determine whether the trachea is palpable at the midline or has shifted to the left or right.

**Mediate Percussion**

Mediate percussion is an examination technique designed to assess lung density, specifically, the air-to-solid ratio in the lungs. 

**Procedure:** Place the middle finger of the nondominant hand flat against the chest wall along an intercostal space. With the tip of the middle finger of the opposite hand, firmly tap on the finger positioned on the chest wall. Repeat the procedure at several points on the right and left anterior and posterior aspects of the chest wall. This maneuver produces a resonance; the pitch varies with the density of the underlying tissue. The subjective determination of pitch indicates the following.

- The sound is dull and flat if there is a greater than normal amount of solid matter (tumor, consolidation) in the lungs in comparison with the amount of air.
- The sound is hyperresonant (tympanic) if there is a greater than normal amount of air in the area (as in patients with emphysema).
- If asymmetrical or abnormal findings are noted, the patient should be referred to the physician for additional objective tests such as a chest radiograph.

**Auscultation of Breath Sounds**

Auscultation is a general term that refers to the process of listening to sounds within the body, specifically to breath sounds during an examination of the lungs. Breath sounds occur because of movement of air in the airways during inspiration and expiration. A stethoscope is used to magnify these sounds. Breath sounds should be assessed to:

- Identify the areas of the lungs in which congestion exists and in which airway clearance techniques should be performed.
- Determine the effectiveness of any airway clearance intervention.

**Extent of excursion.** The extent of chest mobility can be measured by two methods.

- Measure the girth of the chest with a tape measure at three levels (axilla, xiphoid, lower costal). Document change in girth after a maximum inspiration and a maximum expiration.
- Place both hands on the patient’s chest or back as previously described. Note the distance between your thumbs after a maximum inspiration.

**Palpation**

Palpation of the thorax provides evidence of dysfunction of the underlying tissues including the lungs, chest wall, and mediastinum.

**Tactile (vocal) fremitus.** Tactile fremitus is the vibration felt while palpating over the chest wall as a patient speaks.

**Procedure:** Place the palms of your hands lightly on the chest wall and ask the patient to speak a few words or repeat “99” several times. Normally, fremitus is felt unilaterally. Fremitus is increased in the presence of secretions in the airways and decreased or absent when air is trapped as the result of obstructed airways.

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**Procedure:** To identify a mediastinal shift, have the patient sit facing you with the head in midline and the neck slightly flexed to relax the sternocleidomastoid muscles. With your index finger, gently palpate the soft tissue space on either side of the trachea at the suprasternal notch. Determine whether the trachea is palpable at the midline or has shifted to the left or right.

**Mediate Percussion**

Mediate percussion is an examination technique designed to assess lung density, specifically, the air-to-solid ratio in the lungs.

**Procedure:** Place the middle finger of the nondominant hand flat against the chest wall along an intercostal space. With the tip of the middle finger of the opposite hand, firmly tap on the finger positioned on the chest wall. Repeat the procedure at several points on the right and left anterior and posterior aspects of the chest wall. This maneuver produces a resonance; the pitch varies with the density of the underlying tissue. The subjective determination of pitch indicates the following.

- The sound is dull and flat if there is a greater than normal amount of solid matter (tumor, consolidation) in the lungs in comparison with the amount of air.
- The sound is hyperresonant (tympanic) if there is a greater than normal amount of air in the area (as in patients with emphysema).
- If asymmetrical or abnormal findings are noted, the patient should be referred to the physician for additional objective tests such as a chest radiograph.

**Auscultation of Breath Sounds**

Auscultation is a general term that refers to the process of listening to sounds within the body, specifically to breath sounds during an examination of the lungs.

Breath sounds occur because of movement of air in the airways during inspiration and expiration. A stethoscope is used to magnify these sounds. Breath sounds should be assessed to:

- Identify the areas of the lungs in which congestion exists and in which airway clearance techniques should be performed.
- Determine the effectiveness of any airway clearance intervention.
Determine whether the lungs are clear and whether interventions should be discontinued.

Procedure: When assessing breath sounds, be sure the setting is quiet. Have the patient assume a comfortable, relaxed, sitting position to allow access to the chest wall. Place the diaphragm of the stethoscope directly against the patient’s skin along the anterior or posterior chest wall. Be sure that the tubing does not rub together or come in contact with clothing during auscultation, as this contact produces extraneous sounds.

Follow a systematic pattern (Fig. 25.8A&B) and place the stethoscope against specific thoracic landmarks (T2, T6, T10) along the right and left sides of the chest wall. Ask the patient to breathe in deeply and out quickly through the mouth as you move the stethoscope from point to point. Note the quality, intensity, and pitch of the breath sounds.

**Precaution:** Auscultate slowly from one area to another. Allow the patient to breathe in a relaxed manner after several deep breaths to prevent dizziness from hyperventilation. Guard the patient closely to prevent loss of balance if lightheadedness occurs.

Classification of Breath Sounds
Breath sounds are classified by location, pitch, and intensity as well as the ratio of sounds heard on inspiration versus those heard on expiration. Breath sounds also are identified as normal or adventitious (extra).*5,50,52,77

Normal breath sounds occur in the absence of pathology and are heard predominantly during inspiration. Normal breath sounds are categorized as vesicular, bronchial, or bronchovesicular based on the location and quality of the sound. They are described in Box 25.5.*5,57 Adventitious breath sounds are abnormal sounds in the lungs that are heard with a stethoscope. Although terminology in the literature is inconsistent, the nomenclature used most often was proposed by a joint committee of the American College of Chest Physicians and the American Thoracic Society.*3,77 Adventitious breath sounds are categorized as crackles or wheezes. Box 25.5 describes the location and quality of these breath sounds.

**Box 25.5 Normal and Adventitious Breath Sounds**

**Normal Breath Sounds**
- **Vesicular.** Soft, low-pitched, breezy but faint sounds heard over most of the chest except near the trachea and mainstem bronchi and between the scapulae. Vesicular sounds are audible considerably longer on inspiration than expiration (about a 3:1 ratio).
- **Bronchial.** Loud, hollow, or tubular high-pitched sounds heard over the mainstem bronchi and trachea. Bronchial sounds are heard equally during inspiration and expiration; a slight pause in the sound occurs between inspiration and expiration.
- **Bronchovesicular.** Softer than bronchial breath sounds; also heard equally during inspiration and expiration but without a pause in the sound between the cycles. The sounds are heard in the supraclavicular, suprascapular, and parasternal regions anteriorly and between the scapulae posteriorly.

**Adventitious Breath Sounds**
- **Crackles.** Fine, discontinuous sounds (similar to the sound of bubbles popping or the sound of hairs being rubbed between your fingers next to your ear). Crackles, which can be fine or coarse, are heard primarily during inspiration as the result of secretions moving in the Airways or in closed Airways that are rapidly reopening. The former term for crackles was *rales.*
- **Wheeze.** Continuous high- or low-pitched sounds or sometimes musical tones heard during exhalation but occasionally audible during inspiration. Bronchospasm or secretions that narrow the lumen of the Airways cause wheezes. The term previously used for wheezes was *rhonchi.*
Breath sounds may be totally absent or substantially diminished over a portion of the lungs. This indicates total or partial obstruction and lack of aeration of lung tissue. The absence of air and collapse of an area of lung tissue is known as atelectasis. Obstruction of airways may be caused by fluids, mucus, bronchospasm, or compression by tumor.

Cough and Cough Production

The strength, depth, length, and frequency of a patient’s cough must be assessed. An effective cough is sharp and deep. In the patient with current or potential pulmonary dysfunction a cough can be described as weak, shallow, soft, or throaty. A patient may have a weak, shallow cough as the result of pain or paralysis. A sudden onset of a cough or a sustained cough often is described as paroxysmal or spasmodic. If a cough is substantially weak or ineffective, suctioning may be required to clear the airways.*

A cough may be productive or nonproductive in the presence of pathology. The productivity of the cough and secretions produced by the cough should be assessed. Secretions are checked for:

- Color (clear, yellow, green, blood-stained)
- Consistency (viscous, thin, frothy)
- Amount (minimal to copious)
- Odor (no odor to foul-smelling)

Production of a small amount of clear or white secretions on a daily basis is normal. Copious but clear secretions are common with chronic bronchitis. Yellow, green, and purulent secretions with a strong odor are indicative of some type of infection. Blood-streaked secretions, known as hemoptysis, is indicative of some degree of hemorrhage in the lungs. Frothy, white secretions are associated with pulmonary edema and heart failure.

When secretions are produced during the course of interventions, such as exercise or airway clearance, it is the responsibility of the therapist to document the characteristics of the secretions.

Additional Areas of Examination

The examination procedures described in this section are complemented with other areas of examination, which may include a patient’s use of assistive respiratory equipment, ROM particularly of the shoulders, neck, and trunk, muscle strength, general endurance and graded exercise testing, and a patient’s identification of functional abilities or limitations and perceived disability and quality of life.

Breathing Exercises and Ventilatory Training

Breathing exercises and ventilatory training are fundamental interventions for the prevention or comprehensive management of impairments related to acute or chronic pulmonary disorders. For example, these interventions are frequently advocated in the literature for patients with COPD (chronic bronchitis, emphysema, asthma) or cystic fibrosis, for patients with a high spinal cord lesion, for patients who have undergone thoracic or abdominal surgery and are at high risk for acute pulmonary complications, or for patients who must remain in bed for an extended period of time.*

Breathing exercises and ventilatory training can take on many forms including diaphragmatic breathing, segmental breathing, inspiratory resistance training, incentive spirometry, and breathing techniques for the relief of dyspnea during exertion. The goals of these interventions are listed in Box 25.6.

Research studies indicate that although breathing exercises or ventilatory muscle training may affect and possibly alter a patient’s rate and depth of ventilation these interventions may not necessarily have any impact on gas exchange at the alveolar level or on oxygenation.* Therefore, breathing exercises or ventilatory training should be only one aspect of management to improve pulmonary status and to increase a patient’s overall endurance and function during daily living activities. Depending on a patient’s underlying pathology and impairments, exercises to improve ventilation are often combined with medication, airway clearance, the use of respiratory therapy devices, and a graded exercise (aerobic conditioning) program.

Guidelines for Teaching Breathing Exercises

- If possible, choose a quiet area for instruction in which you can interact with the patient with minimal distractions.
- Explain to the patient the aims and rationale of breathing exercises or ventilatory training specific to his or her particular impairments and functional limitations.
- Have the patient assume a comfortable, relaxed position and loosen restrictive clothing. Initially, a semi-Fowler’s position with the head and trunk elevated approximately

* See references 3, 7, 11, 14, 15, 28, 36, 40, 44, 45, 48, 57, 60, 63, 66, 76.
45°, is desirable. By supporting the head and trunk, flexing the hips and knees, and supporting the legs with a pillow, the abdominal muscles remain relaxed. Other positions, such as supine, sitting, or standing, may be used initially or as the patient progresses during treatment.

- Observe and assess the patient’s spontaneous breathing pattern while at rest and later with activity.
- Determine whether ventilatory training is indicated.
- Establish a baseline for assessing changes, progress, and outcomes of intervention.
- If necessary, teach the patient relaxation techniques. This relaxes the muscles of the upper thorax, neck, and shoulders to minimize the use of the accessory muscles of ventilation. Pay particular attention to relaxation of the sternocleidomastoids, upper trapezius, and levator scapulae muscles.
- Depending on the patient’s underlying pathology and impairments, determine whether to emphasize the inspiratory or expiratory phase of ventilation.
- Demonstrate the desired breathing pattern to the patient.
- Have the patient practice the correct breathing pattern in a variety of positions at rest and with activity.

**PRECAUTIONS:** When teaching breathing exercises, be aware of the following precautions:

- Never allow a patient to force expiration. Expiration should be relaxed or lightly controlled. Forced expiration only increases turbulence in the airways, leading to bronchospasm and increased airway restriction.
- Do not allow a patient to take a highly prolonged expiration. This causes the patient to gasp with the next inspiration. The patient’s breathing pattern then becomes irregular and inefficient.
- Do not allow the patient to initiate inspiration with the accessory muscles and the upper chest. Advise the patient that the upper chest should be relatively quiet during breathing.
- Allow the patient to perform deep breathing for only three or four inspirations and expirations at a time to avoid hyperventilation.

**Diaphragmatic Breathing**

When the diaphragm is functioning effectively in its role as the primary muscle of inspiration, ventilation is efficient and the oxygen consumption of the muscles of ventilation is low during relaxed (tidal) breathing. When a patient relies substantially on the accessory muscles of inspiration, the mechanical work of breathing (oxygen consumption) increases and the efficiency of ventilation decreases. Although the diaphragm controls breathing at an involuntary level, a patient with primary or secondary pulmonary dysfunction can be taught how to control breathing by optimal use of the diaphragm and decreased use of accessory muscles.

Controlled breathing techniques, which emphasize diaphragmatic breathing, are designed to improve the efficiency of ventilation, decrease the work of breathing, increase the excursion (descent or ascent) of the diaphragm, and improve gas exchange and oxygenation. Diaphragmatic breathing exercises also are used during postural drainage to mobilize lung secretions.

**PROCEDURE**

- Prepare the patient in a relaxed and comfortable position in which gravity assists the diaphragm, such as a semi-Fowler’s position.
- If your examination revealed that the patient initiates the breathing pattern with the accessory muscles of inspiration (shoulder and neck musculature), start instruction by teaching the patient how to relax those muscles (shoulder rolls or shoulder shrugs coupled with relaxation).
- Place your hand(s) on the rectus abdominis just below the anterior costal margin (Fig. 25.9). Ask the patient to breathe in slowly and deeply through the nose. Have the patient keep the shoulders relaxed and upper chest quiet, allowing the abdomen to rise slightly. Then tell the patient to relax and exhale slowly through the mouth.

**FIGURE 25.9** The semireclining (as shown) and semi-Fowler’s positions are comfortable, relaxed positions in which to teach diaphragmatic breathing.
Deep breathing while focusing on movement of the lower portion of the rib cage may facilitate diaphragmatic excursion. This technique is particularly important for the patient with a stiff lower rib cage, as is often seen with chronic bronchitis, emphysema, or asthma.

**Procedure**

- Have the patient begin in a hook-lying position; later progress to a sitting position. Place your hands along the lateral aspect of the lower ribs to direct the patient’s attention to the areas where movement is to occur (Figs. 25.11 and 25.12).

**NOTE:** Evidence concerning the effect of diaphragmatic breathing exercises on the rate of ventilation, the work of breathing and oxygen consumption, excursion of the diaphragm, and exercise capacity in normal subjects and in patients with pulmonary disorders is inconclusive, with some studies supporting and others refuting the benefits of diaphragmatic breathing.

**Segmental Breathing**

It is questionable whether a patient can be taught to expand localized areas of the lungs while keeping other areas quiet. It is known, however, that hypoventilation does occur in certain areas of the lungs because of chest wall fibrosis, pain, and muscle guarding after surgery, atelectasis, and pneumonia. Therefore, there are certain instances such as during postural drainage or following thoracic surgery when it is important to emphasize expansion of problem areas of the lungs and chest wall.

Two examples of segmental breathing that target the lateral and posterior segments of the lower lobes are described in this section. However, segmental breathing techniques also may need to be directed to the middle and upper lobes if there is accumulation of secretions or insufficient lung expansion in these areas.

**Lateral Costal Expansion**

Lateral costal expansion, sometimes called lateral basal expansion, can be carried out unilaterally or bilaterally.

- After the patient understands and is able to control breathing using a diaphragmatic pattern, keeping the shoulders relaxed, practice diaphragmatic breathing in a variety of positions (sitting, standing) and during activity (walking, climbing stairs).

**FIGURE 25.10** The patient places his or her own hands on the abdomen to feel the movement of proper diaphragmatic breathing. By placing the hands on the abdomen, the patient can also feel the contraction of the abdominals, which occurs with controlled expiration or coughing.

**FIGURE 25.11** Bilateral lateral costal expansion—supine.

**FIGURE 25.12** Bilateral lateral costal expansion—sitting.

- Ask the patient to breathe out, and feel the rib cage move downward and inward. As the patient breathes out, place pressure into the ribs with the palms of your hands.
- Just prior to inspiration, apply a quick downward and inward stretch to the chest. This places a quick
stretch on the external intercostals to facilitate their contraction.

- Apply light manual resistance to the lower ribs to increase sensory awareness as the patient breathes in deeply and the chest expands and ribs flare. Then, as the patient breathes out, assist by gently squeezing the rib cage in a downward and inward direction.

- Teach the patient how to perform the maneuver independently by placing his or her hand(s) over the ribs (Fig. 25.13) or applying resistance with a towel or belt around the lower ribs (Fig. 25.14A&B).

Pursed-Lip Breathing

Pursed-lip breathing is a strategy that involves lightly pursing the lips together during controlled exhalation. This breathing pattern often is adopted spontaneously by patients with COPD to deal with episodes of dyspnea. Patients with COPD using pursed-lip breathing report a decrease in their perceived level of exertion during activity. However, whether it is beneficial to teach a patient pursed-lip breathing often is debated. Many therapists believe that gentle pursed-lip breathing and controlled expiration is a useful procedure, particularly to relieve dyspnea if it is performed appropriately. It is thought to keep airways open by creating back-pressure in the airways. Studies suggest that pursed-lip breathing decreases the respiratory rate and the work of breathing (oxygen consumption), increases the tidal volume, and improves exercise tolerance.

**PRECAUTION**: The use of forceful expiration during pursed-lip breathing must be avoided. Forceful expiration while the lips are pursed can increase the turbulence in the airways and cause further restriction of the small bronchioles. Therefore, if a therapist elects to teach this breathing strategy, it is important to emphasize with the patient that expiration should be performed in a controlled manner but not forced.

**Procedure**

Have the patient sit and lean forward on a pillow, slightly bending the hips (see Fig. 25.15). Place your hands over the posterior aspect of the lower ribs, and follow the same procedure just described for lateral costal expansion.

**Posterior Basal Expansion**

Deep breathing emphasizing posterior basal expansion is important for the postsurgical patient who is confined to bed in a semireclining position for an extended period of time because secretions often accumulate in the posterior segments of the lower lobes.

**Procedure**

Have the patient sit and lean forward on a pillow, slightly bending the hips (see Fig. 25.15). Place your hands over the posterior aspect of the lower ribs, and follow the same procedure just described for lateral costal expansion.
After each pursed-lip expiration, teach the patient to use diaphragmatic breathing and minimize use of accessory muscles during each inspiration. Have the patient remain in a forward-bent posture and continue to breathe in a slow, controlled manner until the episode of dyspnea subsides.

Positive Expiratory Pressure Breathing
Positive expiratory pressure breathing is a technique in which resistance to airflow is applied during exhalation, similar to what occurs during pursed-lip breathing, except that the patient breathes through a specially designed mouthpiece or mask that controls resistance to airflow. This breathing technique is used to hold airways open during exhalation to mobilize accumulated secretions and improve their clearance. Positive expiratory pressure breathing provides an alternative or adjunct to postural drainage which a patient can perform independently.

Procedure
Positive expiratory pressure breathing is performed in an upright position, preferably seated with the elbows resting on a table. The procedure can be performed against low or high pressure. A low pressure technique involves tidal inspiration and active, but not forced, expiration through a mouthpiece or mask. The patient inhales, holds the inspiration for 2 to 3 seconds, and then exhales, repeating the sequence for approximately 10 to 15 cycles. The patient removes the mouthpiece or mask, takes several “huffs” and then coughs to clear the mobilized secretions from the airways. The breathing sequence typically is repeated four to six times with a total treatment session lasting about 15 minutes.

Preventing and Relieving Episodes of Dyspnea
Many patients with COPD (e.g., emphysema and asthma) may suffer from periodic episodes of dyspnea (shortness of breath), particularly with physical exertion or when in contact with allergens. Whenever a patient’s normal breathing pattern is interrupted, shortness of breath can occur. It is helpful to teach a patient how to monitor his or her level of shortness of breath and to prevent episodes of dyspnea by controlled breathing techniques, pacing activities, and becoming aware of what activity or situation precipitates a shortness of breath attack.

Pacing is the performance of functional activities, such as walking, stair climbing, or work-related tasks, within the limits of a patient’s ventilatory capacity. Although some patients may understand intuitively the limits to which functional activities can be pushed, others must be taught to recognize the early signs of dyspnea. If the patient becomes slightly short of breath, he or she must learn to stop an activity and use controlled, pursed-lip breathing until the dyspnea subsides.

Procedure
- Have the patient assume a relaxed, forward-bent posture (Figs. 25.15 and 25.16; also see Fig. 25.6). A forward-bent position stimulates diaphragmatic breathing (the viscera drop forward and the diaphragm descends more easily). Use bronchodilators as prescribed.
- Have the patient gain control of his or her breathing and reduce the respiratory rate by using pursed-lip breathing during expiration. Have the patient focus on the expiratory phase of breathing while being sure to avoid forceful expiration.

After each pursed-lip expiration, teach the patient to use diaphragmatic breathing and minimize use of accessory muscles during each inspiration.
- Have the patient remain in a forward-bent posture and continue to breathe in a slow, controlled manner until the episode of dyspnea subsides.

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Respiratory Resistance Training

The process of improving the strength or endurance of the muscles of ventilation is known as respiratory resistance training (RRT). Other descriptions used to denote this form of breathing exercises are ventilatory muscle training, inspiratory (or expiratory) muscle training, inspiratory resistance training, and flow-controlled endurance training. These techniques typically focus on training the muscles of inspiration, although expiratory muscle training also has been described. RRT is advocated to improve ventilation in patients with pulmonary dysfunction associated with weakness, atrophy, or inefficiency of the muscles of inspiration or to improve the effectiveness of the cough mechanism in patients with weakness of the abdominal muscles or other expiratory muscles.

With support from animal studies, it has been suggested that the principles of overload and specificity of training apply to skeletal muscles throughout the body, including the muscles of ventilation. In humans, it is not feasible to use invasive procedures to evaluate morphological or histochemical changes in the diaphragm that may occur as the result of strength or endurance training. Instead, strength or endurance changes must be assessed indirectly. Increases in respiratory muscle strength and endurance are determined by ultrasonographic measurements of the thickness of the diaphragm, maximal voluntary ventilation, and decreased reliance on accessory muscles of inspiration. Respiratory muscle strength (either inspiratory or expiratory) also is evaluated indirectly with measurements of inspiratory capacity, forced expiratory volume, inspiratory mouth pressure using a spirometer, vital capacity, and increased cough effectiveness.

**PRECAUTION:** Avoid prolonged periods of any form of resistance training for inspiratory muscles. Unlike muscles of the extremities, the diaphragm cannot totally rest to recover from a session of resistance exercises. Use of accessory muscles of inspiration (neck and shoulder muscles) is a sign that the diaphragm is beginning to fatigue.

Inspiratory Resistance Training

Inspiratory resistance training, using pressure- or flow-based devices to provide resistance to airflow, is designed to improve the strength and endurance of the muscles of inspiration and decrease the occurrence of inspiratory muscle fatigue. This technique has been studied in patients with acute and chronic, primary and secondary pulmonary disorders, including COPD, cystic fibrosis, respiratory failure and ventilator dependence (weaning failure), chronic heart failure, and chronic neuromuscular disease. Although reviews of the literature have demonstrated that outcomes of inspiratory muscle training programs in patients with pathologies are inconsistent, some positive changes reported after training are increased vital capacity, increased exercise capacity, and fewer episodes of dyspnea. Inspiratory muscle training also has been studied and found to be effective (as evidenced by a decreased respiratory rate) in patients with cervical-level spinal cord lesions.

**Procedure**

- The patient inhales through a resistive training device placed in the mouth. These devices are narrow tubes of varying diameters or a mouthpiece and adapter with an adjustable aperture that provide resistance to airflow during inspiration and therefore place resistance on inspiratory muscles. The smaller the diameter of the aperture and the faster the rate of airflow, the greater is the resistance.
- The patient inhales through the device for a specified period of time several times each day. The time is gradually increased to 20 to 30 minutes at each training session to increase inspiratory muscle endurance.

Incentive Respiratory Spirometry

Incentive spirometry is a form of ventilatory training that emphasizes sustained maximum inspirations. The patient inhales as deeply as possible through a small, handheld spirometer that provides visual or auditory feedback about whether a target maximum inspiration was reached. Typically, this breathing technique is performed while using a spirometer, but it also may be performed without the equipment.

The purpose of incentive spirometry is to increase the volume of air inspired. It is used primarily to prevent alveolar collapse and atelectasis in postoperative patients. Despite the widespread use of incentive spirometry for patients after surgery, the effectiveness of this technique alone or in addition to general deep breathing and coughing for the prevention of postoperative pulmonary complications is not clear.

**Procedure**

- Have the patient assume a comfortable position (semireclining, if possible) and inhale and exhale three to four times and then exhale maximally with the fourth breath.
- Then have the patient place the spirometer in the mouth, inhale maximally through the mouthpiece to a target setting and hold the inspiration for several seconds.
- This sequence is repeated five to ten times several times per day.

Glossopharyngeal Breathing

Glossopharyngeal breathing is a technique that became known to therapists during the 1950s through patients with severe ventilatory impairment as the result of poliomyelitis. It is a means of increasing the inspiratory capacity when there is severe weakness of the muscles of inspiration. Today, it is used primarily by patients who are ventilator-dependent because of absent or incomplete innervation of the diaphragm as the result of a high cervical-level spinal cord lesion or other neuromuscular disorders. Glossopharyngeal breathing combined with the inspiratory action of the neck musculature can reduce ventilator dependence or can be used as an emergency procedure should a malfunction of a patient’s ventilator...
It also can be used to improve the force (and therefore the effectiveness) of a cough or increase the volume of the voice.

**Procedure**

Glossopharyngeal breathing involves taking several “gulps” of air, usually 6 to 10 gulps in series, to pull air into the lungs when action of the inspiratory muscles is inadequate. After the patient takes several gulps of air, the mouth is closed, and the tongue pushes the air back and traps it in the pharynx. The air is then forced into the lungs when the glottis is opened. This increases the depth of the inspiration and the patient’s inspiratory and vital capacities.39,75

**EXERCISES TO MOBILIZE THE CHEST**

Chest mobilization exercises are any exercises that combine active movements of the trunk or extremities with deep breathing.21,60 They are designed to maintain or improve mobility of the chest wall, trunk, and shoulder girdles when it affects ventilation or postural alignment. For example, a patient with hypomobility of the trunk muscles on one side of the body does not expand that part of the chest fully during inspiration. Exercises that combine stretching of these muscles with deep breathing improve ventilation on that side of the chest.

Chest mobilization exercises also are used to reinforce or emphasize the depth of inspiration or controlled expiration. A patient can reinforce expiration, for example, by leaning forward at the hips or flexing the spine as he or she breathes out. This pushes the viscera superiorly into the diaphragm.

**Specific Techniques**

**To Mobilize One Side of the Chest**

- While sitting, have the patient bend away from the tight side to lengthen hypomobile structures and expand that side of the chest during inspiration (Fig. 25.17A).
- Then, have the patient push the fisted hand into the lateral aspect of the chest, bend toward the tight side, and breathe out (Fig. 25.17B).
- Progress by having the patient raise the arm overhead on the tight side of the chest and side-bend away from the tight side. This places an additional stretch on hypomobile tissues.

**To Mobilize the Upper Chest and Stretch the Pectoralis Muscles**

- While the patient is sitting in a chair with both hands clasped behind the head, have him or her horizontally abduct the arms (elongating the pectoralis major) during a deep inspiration (Fig. 25.18A).
- Then instruct the patient to bring the elbows together and bend forward during expiration (Fig. 25.18B).

**To Mobilize the Upper Chest and Shoulders**

While sitting in a chair, have the patient reach with both arms overhead (180° bilateral shoulder flexion and slight abduction) during inspiration (Fig. 25.19A) and then bend forward at the hips and reach for the floor during expiration (Fig. 25.19B).
An effective cough is necessary to eliminate respiratory obstructions and keep the lungs clear. Airway clearance is an important part of management of patients with acute or chronic respiratory conditions.25,51,60

The Normal Cough Pump

A cough may be reflexive or voluntary. When a person coughs, a series of actions occurs (Box 25.7).47 Under normal conditions, the cough pump is effective to the seventh generation of bronchi. (There are a total of 23 generations of bronchi in the tracheobronchial tree.) Ciliated epithelial cells are present up to the terminal bronchiole and raise secretions from the smaller to the larger airways in the absence of pathology.

Factors that Decrease the Effectiveness of the Cough Mechanism and Cough Pump

The effectiveness of the cough mechanism can be compromised for a number of reasons including the following.25,51,60,76

1. Decreased inspiratory capacity. Inspiratory capacity can be reduced because of pain due to acute lung disease, rib fracture, trauma to the chest, or recent thoracic or abdominal surgery. Weakness of the diaphragm or accessory muscles of inspiration as a result of a high spinal cord injury or neuropathic or myopathic disease decrease a patient’s ability to take in a deep breath. Postoperatively, the respiratory center may be depressed as the result of general anesthesia, pain, or medication.

2. Inability to forcibly expel air. A spinal cord injury above T12 and myopathic disease, such as muscular dystrophy, cause weakness of the abdominal muscles, which are vital for a strong cough. Excessive fatigue as the result of critical illness and a chest wall or abdominal incision causing pain all contribute to a weak cough. A patient who has had a tracheostomy also has difficulty producing a strong cough, even when the tracheostomy site is covered.

3. Decreased action of the cilia in the bronchial tree. Action of the ciliated cells may be compromised because of physical interventions such as general anesthesia and intubation or pathologies such as COPD including chronic bronchitis, which is associated with a decreased number of ciliated epithelial cells in the airway. Smoking also depresses the action of the cilia.

4. Increase in the amount or thickness of mucus. Pathologies (e.g., cystic fibrosis, chronic bronchitis) and pulmonary infections (e.g., pneumonia) are associated with an increase in mucus production and the thickness of the mucus. Intubation irritates the lumen of the airways and causes increased mucus production, whereas dehydration thickens mucus.

Teaching an Effective Cough

Because an effective cough is an integral component of airway clearance, a patient must be taught the importance of an effective cough, how to produce an efficient and controlled voluntary cough, and when to cough. The following sequence and procedures are used when teaching an effective cough.25,51,66

1. Assess the patient’s voluntary or reflexive cough.
2. Have the patient assume a relaxed, comfortable position for deep breathing and coughing. Sitting or leaning forward usually is the best position for coughing. The patient’s neck should be slightly flexed to make coughing more comfortable.
3. Teach the patient controlled diaphragmatic breathing, emphasizing deep inspirations.
4. Demonstrate a sharp, deep, double cough.
5. Demonstrate the proper muscle action of coughing (contraction of the abdominals). Have the patient place the hands on the abdomen and make three huffs with expiration to feel the contraction of the abdominals (see Fig. 25.10). Have the patient practice making a “K” sound to experience tightening the vocal cords, closing the glottis, and contracting the abdominals.
6. When the patient has put these actions together, instruct the patient to take a deep but relaxed inspiration, fol-
Avoid direct pressure on the xiphoid process during the maneuver.

Self-Assisted Technique

While in a sitting position, the patient crosses the arms across the abdomen or places the interlocked hands below the xiphoid process (see Fig. 25.21). After the patient inhales as deeply as possible, the therapist manually assists the patient as he or she attempts to cough. The abdomen is compressed with an inward and upward force, which pushes the diaphragm upward to cause a more forceful and effective cough.

This same maneuver can be performed with the patient in a chair (Fig. 25.21). The therapist or family member can stand in back of the patient and apply manual pressure during expiration.

Splinting

If chest wall pain from recent surgery or trauma is restricting the cough, teach the patient to splint over the painful area during coughing. Have the patient press the hands or a pillow firmly over the incision to support the painful area with each cough (Fig. 25.22). If the patient cannot reach the painful area, the therapist should assist (Fig. 25.23).

Humidification

If secretions are very thick, work with the patient after humidification therapy or ultrasonic nebulizer therapy, both

LOWED BY A SHARP DOUBLE COUGH. THE SECOND COUGH DURING A SINGLE EXPIRATION IS USUALLY MORE PRODUCTIVE.

7. Use an abdominal binder or glossopharyngeal breathing in selected patients with inspiratory or abdominal muscle weakness to enhance the cough, if necessary.

Precautions that should be observed while teaching a patient an effective cough are noted in Box 25.8.

Additional Techniques to Facilitate a Cough and Improve Airway Clearance

To maximize airway clearance, several techniques can be used to stimulate a stronger cough, make coughing more comfortable or improve the clearance of secretions.

Manual-Assisted Cough

If a patient has abdominal weakness (e.g., as the result of a mid-thoracic or cervical spinal cord injury), manual pressure on the abdominal area assists in developing greater intra-abdominal pressure for a more forceful cough. Manual pressure for cough assistance can be applied by the therapist or the patient.

Therapist-Assisted Techniques

With the patient in a supine or semireclining position, the therapist places the heel of one hand on the patient’s abdomen at the epigastric area just distal to the xiphoid process. The other hand is placed on top of the first, keeping the fingers open or interlocking them (Fig. 25.20). After the patient inhales as deeply as possible, the therapist manually assists the patient as he or she attempts to cough. The abdomen is compressed with an inward and upward force, which pushes the diaphragm upward to cause a more forceful and effective cough.

This same maneuver can be performed with the patient in a chair (Fig. 25.21). The therapist or family member can stand in back of the patient and apply manual pressure during expiration.

Precautions for Teaching an Effective Cough

- Never allow a patient to gasp in air, because this increases the work (energy expenditure) of breathing, causing the patient to fatigue more easily. It also increases turbulence and resistance in the airways, possibly leading to increased bronchospasm and further constriction of airways. A gasping action may also push mucus or a foreign object deep into air passages.
- Avoid uncontrolled coughing spasms (paroxysmal coughing).
- Avoid forceful coughing if a patient has a history of a cerebrovascular accident or an aneurysm. Have these patients huff several times to clear the airways, rather than cough.
- Be sure that the patient coughs while in a somewhat erect or side-lying posture.

PRECAUTION: Avoid direct pressure on the xiphoid process during the maneuver.

Self-Assisted Technique

- While in a sitting position, the patient crosses the arms across the abdomen or places the interlocked hands below the xiphoid process (see Fig. 25.21).
- After a deep inspiration, the patient pushes inward and upward on the abdomen with the wrists or forearms and simultaneously leans forward while attempting to cough.

Splinting

If chest wall pain from recent surgery or trauma is restricting the cough, teach the patient to splint over the painful area during coughing. Have the patient press the hands or a pillow firmly over the incision to support the painful area with each cough (Fig. 25.22). If the patient cannot reach the painful area, the therapist should assist (Fig. 25.23).

Humidification

If secretions are very thick, work with the patient after humidification therapy or ultrasonic nebulizer therapy, both
of which enhance the mucociliary transport system and facilitate a productive cough.66

Tracheal Stimulation
Tracheal stimulation, sometimes called a tracheal tickle, may be used with infants or disoriented patients who cannot cooperate during treatment.66 Tracheal stimulation is a somewhat uncomfortable maneuver, performed to elicit a reflexive cough. The therapist places two fingers at the sternal notch and applies a circular motion with pressure downward into the trachea to facilitate a reflexive cough.

Suctioning: Alternative to Coughing
Endotracheal suctioning may be the only means of clearing the airways in patients who are unable to cough or huff voluntarily or after reflex stimulation of the cough mechanism.29,60 Suctioning is indicated in all patients with artificial airways. The suctioning procedure clears only the trachea and the mainstem bronchi.

PRECAUTION: Only individuals who have been taught proper suctioning technique should use this alternative means of clearing the airways. Suctioning, if performed incorrectly, can introduce an infection into the airways or damage the delicate mucosal lining of the trachea and bronchi. Improper suctioning also can cause hypoxemia, an abnormal heart rate, and atelectasis. A complete description of the proper endotracheal suctioning technique may be found in other resources.29,60

POSTURAL DRAINAGE
Postural drainage (bronchial drainage), another intervention for airway clearance, is a means of mobilizing secretions in one or more lung segments to the central airways by placing the patient in various positions so gravity assists in the drainage process.4,11,25,51,60 When secretions are moved from the smaller to the larger airways, they are then cleared by coughing or endotracheal suctioning. Postural drainage therapy also includes the use of manual techniques, such as percussion, shaking, and vibration, coupled with voluntary coughing.

Goals and indications for postural drainage are noted in Box 25.9, and relative contraindications are summarized in Box 25.10.4,11,25,51,60 Despite the risks, postural drainage may be necessary in the unstable patient. Modified positioning to avoid head-down or fully horizontal positions typically is necessary for most high-risk patients.

Manual Techniques Used with Postural Drainage Therapy
In addition to the use of body positioning, deep breathing, and an effective cough to facilitate airway clearance, a variety of manual techniques are used in conjunction with postural drainage to maximize the effectiveness of the

BOX 25.9 Goals and Indications for Postural Drainage

Prevent Accumulation of Secretions in Patients at Risk for Pulmonary Complications
- Patients with pulmonary diseases that are associated with increased production or viscosity of mucus, such as chronic bronchitis and cystic fibrosis
- Patients who are on prolonged bed rest
- Patients who have received general anesthesia and who may have painful incisions that restrict deep breathing and coughing postoperatively
- Any patient who is on a ventilator if he or she is stable enough to tolerate the treatment

Remove Accumulated Secretions from the Lungs
- Patients with acute or chronic lung disease, such as pneumonia, atelectasis, acute lung infections, COPD
- Patients who are generally very weak or are elderly
- Patients with artificial airways
The therapist’s cupped hands strike the patient’s chest wall in an alternating, rhythmic manner (Fig. 25.24B). The therapist should try to keep shoulders, elbows, and wrists loose and mobile during the maneuver. Mechanical percussion is an alternative to manual percussion techniques.

Percussion is continued for several minutes or until the patient needs to alter position to cough. This procedure should not be painful or uncomfortable.

PRECAUTIONS: To prevent irritation to sensitive skin, have the patient wear a lightweight gown or shirt. Avoid percussion over breast tissue in women and over bony prominences.

Relative Contraindications to Percussion
Prior to using percussion in a postural drainage program, a therapist must weigh the potential benefits versus potential risks. In most instances, it is prudent to avoid the use of percussion. Over fractures, spinal fusion, or osteoporotic bone. Over tumor area. If a patient has a pulmonary embolus. If the patient has a condition in which hemorrhage could easily occur, such as in the presence of a low platelet count, or if the patient is receiving anticoagulation therapy. If the patient has unstable angina. If the patient has chest wall pain, for example after thoracic surgery or trauma.

Vibration
Vibration, another manual technique, often is used in conjunction with percussion to help move secretions to larger airways. It is applied only during the expiratory phase as the patient is deep-breathing. Vibration is applied by placing both hands directly on the skin and over the chest wall (or one hand on top of the other) and gently compressing and rapidly vibrating the chest wall as the patient breathes out (Fig. 25.25). Pressure is applied in the same direction as the chest is moving. The vibrating action is achieved by the therapist isometrically contracting (tensing) the muscles of the upper extremities from shoulders to hands.
Shaking
Shaking is a more vigorous form of vibration applied during exhalation using an intermittent bouncing maneuver coupled with wide movements of the therapist’s hands. The therapist’s thumbs are locked together, the open hands are placed directly on the patient’s skin, and fingers are wrapped around the chest wall. The therapist simultaneously compresses and shakes the chest wall.25,51,72

Postural Drainage Positions
Positions for postural drainage are based on the anatomy of the lungs and the tracheobronchial tree (see Figs. 25.2 and 25.4). Each segment of each lobe is drained using the positions depicted in Figures 25.26 through 25.37. The shaded area in each illustration indicates the area of the chest wall where percussion or vibration is applied.

RIGHT AND LEFT UPPER LOBES

![Anterior apical segments](image1)

**FIGURE 25.26** Percussion is applied directly under the clavicle.

![Posterior apical segments](image2)

**FIGURE 25.27** Percussion is applied above the scapulae. Your fingers curve over the top of the shoulders.

![Anterior segments](image3)

**FIGURE 25.28** Percussion is applied bilaterally, directly over the nipple or just above the breast.

![Posterior segment (left)](image4)

**FIGURE 25.29** Patient lies one-quarter turn from prone and rests on the right side. Head and shoulders are elevated 45° or approximately 18 inches if pillows are used. Percussion is applied directly over the left scapula.

![Posterior segment (right)](image5)

**FIGURE 25.30** Patient lies flat and one-quarter turn from prone on the left side. Percussion is applied directly over the right scapula.
FIGURE 25.31 Patient lies one-quarter turn from supine on the right side, supported with pillows and in a 30° head-down position. Percussion is applied just under the left breast.

FIGURE 25.32 Patient lies one-quarter turn from supine on the left side, supported with pillows behind the back, and in a 30° head-down position. Percussion is applied under the right breast.

FIGURE 25.33 Patient lies supine, pillows under knees, in a 45° head-down position. Percussion is applied bilaterally over the lower portion of the ribs.

FIGURE 25.34 Patient lies prone with a pillow under the abdomen in a 45° head-down position. Percussion is applied bilaterally over the lower portion of the ribs.

FIGURE 25.35 Patient lies on the right side in a 45° head-down position. Percussion is applied over the lower lateral aspect of the left rib cage.

FIGURE 25.36 Patient lies on the left side in a 45° head-down position. Percussion is applied over the lower lateral aspect of the right rib cage.

FIGURE 25.37 Patient lies prone with a pillow under the abdomen to flatten the back. Percussion is applied bilaterally, directly below the scapulae.
The patient may be positioned on a postural drainage table that can be elevated at one end, a tilt table, a reinforced padded table with a lift, or a hospital bed. A small child can be positioned on a therapist’s or parent’s lap.

**Guidelines for Implementing Postural Drainage**

**General Considerations**

**Time of day.** Consider the following when scheduling postural drainage into a patient’s day.

- Never administer postural drainage directly after a meal.
- Coordinate treatment with aerosol therapy. Some therapists believe that aerosol therapy combined with humidification prior to postural drainage helps loosen secretions and increases the likelihood of productivity. Others believe that aerosol therapy is best after postural drainage when the patient’s lungs are clearer and maximal benefit can be gained from medication administered through aerosol therapy.
- Choose a time (or times) of day likely to be of most benefit to the patient. A patient’s cough tends to be highly productive in the early morning because of accumulation of secretions from the night before. Postural drainage in the early evening clears the lungs prior to sleeping and helps the patient rest more easily.

**Frequency of treatments.** The frequency of postural drainage each day or during the week depends on the type and severity of a patient’s pathology. If secretions are thick and copious, two to four times per day may be necessary until the lungs are clear. If a patient is on a maintenance program, the frequency is less, perhaps once a day or only a few days a week.

**Preparation for Postural Drainage**

- Loosen tight or bulky clothing. It is not necessary to expose the skin. The patient may wear a lightweight shirt or gown.
- Have a sputum cup or tissues available.
- Have sufficient pillows for positioning and comfort.
- Explain the treatment procedure to the patient.
- Teach the patient deep breathing and an effective cough.
- If the patient is producing copious amounts of sputum, instruct the patient to cough a few times or have the patient suctioned prior to positioning.
- Make any adjustments of tubes and wires, such as chest tubes, electrocardiography wires, or catheters, so they remain clear during positioning.

**Postural Drainage Sequence**

- Determine which segments of the lungs should be drained. Some patients with chronic lung diseases, such as cystic fibrosis, need to be drained in all positions. Other patients may require drainage of only a few segments in which secretions have accumulated.
- Check the patient’s vital signs and breath sounds.
- Position the patient in the correct position for drainage. See that he or she is as comfortable and relaxed as possible.
- Stand in front of the patient, whenever possible, to observe his or her color.
- Maintain each position for 5 to 10 minutes if the patient can tolerate it or as long as the position is productive.
- Have the patient breathe deeply during drainage but do not allow the patient to hyperventilate or become short of breath. Pursed-lip breathing during expiration is sometimes used.
- Apply percussion over the segment being drained while the patient is in the correct position.
- Encourage the patient to take a deep, sharp, double cough whenever necessary. It may be more comfortable for the patient to momentarily assume a semiupright position (resting on one elbow) and then cough.
- If the patient does not cough spontaneously during positioning with percussion, instruct the patient to take several deep breaths or huff several times in succession as you apply vibration during expiration. This may help elicit a cough.
- If the patient’s cough is not productive after 5 to 10 minutes of positioning, go on to the next position. Secretions that have been mobilized during a treatment may not be coughed up by the patient until 30 minutes to 1 hour after treatment.
- The duration of any one treatment should not exceed 45 to 60 minutes, as the procedure is quite fatiguing for the patient.

**Concluding a Treatment**

- Have the patient sit up slowly and rest for a short while after the treatment. Watch for signs of postural hypotension when the patient rises from a supine position or from a head-down position to sitting.
- Advise the patient that even if the cough was not productive during treatment it may be productive a short while after treatment.
- Evaluate the effectiveness of the treatment by reassessing breath sounds.
- Note the type, color, consistency, and amount of secretions produced.
- Check the patient’s vital signs after treatment and note how the patient tolerated the treatment.

**Criteria for Discontinuing Postural Drainage**

- If the chest radiograph is relatively clear
- If the patient is afebrile for 24 to 48 hours
- If normal or near-normal breath sounds are heard with auscultation
- If the patient is on a regular home program

**Modified Postural Drainage**

Some patients who require postural drainage cannot assume or cannot tolerate the positions optimal for postural
drainage. For example, a patient with congestive heart failure may exhibit indications of orthopnea (shortness of breath while lying flat). After neurosurgery a patient may not be allowed to assume a head-down (Trendelenburg) position because this position causes increased intracranial pressure. After thoracic surgery a patient may have chest tubes and monitoring wires that limit positioning. Under these circumstances and others, positioning during postural drainage must be modified. The positions in which postural drainage is undertaken are modified consistent with the patient’s medical or surgical problems. This compromise, although not ideal, is better than not administering postural drainage at all.

Home Program of Postural Drainage

Postural drainage may have to be carried out on a regular basis at home for patients with chronic lung disease. Patients need to be shown how to position themselves using inexpensive aids. An adult may place pillows over a hard wedge or stacks of newspapers to achieve the desired head-down positions in bed. A patient also can lean the chest over the edge of a bed, resting with the arms on a chair or stool. A child can be positioned on an ironing board propped up against a sofa or heavy chair. A family member often must be taught proper positioning, percussion or shaking techniques, and precautions to assist the patient.

**Management of Patients with Chronic Obstructive Pulmonary Disease**

Chronic obstructive pulmonary disease is a broad term encompassing a number of chronic pulmonary conditions, all of which obstruct the flow of air in the conducting airways of the lower respiratory tract and alter ventilation and gas exchange. Although a variety of pulmonary diseases are classified as obstructive in nature, each disease has its unique features and clinical manifestations and is distinguished by the cause of the obstruction of airflow, the onset of the disease, the location of the obstruction, and the reversibility of the obstruction.

Types of Obstructive Pulmonary Disorders

Typically, peripheral airway disease, chronic bronchitis, and emphysema are classified as COPD; but other obstructive pulmonary diseases that are chronic in nature, such as asthma, bronchiectasis, cystic fibrosis, and bronchopulmonary dyplasia, also may be included under this broad descriptor. The focus of discussion and guidelines for management presented in this section of the chapter is on chronic bronchitis and emphysema because patients with these diseases commonly are seen in pulmonary rehabilitation programs.

Pathological Changes in the Pulmonary System

Changes in chronic bronchitis and emphysema that occur over time are inflammation of the mucous membranes of the airways; increased production and retention of mucus; narrowing and destruction of airways; and destruction of alveolar and bronchial walls. These structural changes are reflected in pulmonary function tests depicted in Figure 25.38. These changes in the patient’s pulmonary status predispose the patient to frequent acute respiratory infections.

Impairments and Impact on Function

As a result of the pathophysiology of COPD, many physical impairments develop over time. Patients typically have a chronic, productive cough and are often short of breath. The characteristic impact of COPD on the pulmonary system is the inability to remove air from the lungs effectively, which in turn affects the ability of the respiratory system to transport oxygen into the lungs.

Consequently, functional limitations and eventually disability occur consistent with the disablment process. Impairments such as increased respiratory rate, decreased vital capacity and forced expiratory volume, increased use of accessory muscles of inspiration, and progressive chest wall stiffness are associated with decreased tolerance to exercise, frequent episodes of dyspnea, decreased walking speed and distance, and eventual inability to perform activities of daily living at home or in the workplace or to remain an active participant in the community.
Management Guidelines: COPD

Lifelong management includes appropriate medical management to lessen disabling symptoms and prevent infection, smoking cessation, and participation in a comprehensive pulmonary rehabilitation program. Important aspects of management include breathing exercises, ongoing, airway clearance, and participation in an individually designed, graded exercise program that includes upper and lower extremity strength training and aerobic conditioning. Common impairments and guidelines for management are described in Box 25.11.

Focus on Evidence

Patients with COPD who appear to benefit most from pulmonary rehabilitation are those with only moderate-level disease and without a substantial number of co-morbidities. A combination of upper and lower extremity exercises have been shown to improve functional status more effectively than either upper or lower extremity exercise alone. Systematic reviews of the literature of pulmonary rehabilitation programs have demonstrated that the effects of a program of breathing exercises (diaphragmatic and pursed-lip breathing) on respiratory function and the effects of inspiratory resistance training on exercise capacity are equivocal. However, peripheral muscle strengthening programs improve physical functioning.

MANAGEMENT OF PATIENTS WITH RESTRICTIVE PULMONARY DISORDERS

Restrictive pulmonary disorders are characterized by the inability of the lungs to expand fully as a result of extrapulmonary and/or pulmonary disease or restriction. In other words, the patient has difficulty taking in a deep breath.

Acute and Chronic Causes of Restrictive Pulmonary Disorders

There are a variety of acute or chronic disorders directly involving structures of the pulmonary system or extrapulmonary disorders that can cause restrictive pulmonary dysfunction. In other words, the patient has difficulty taking in a deep breath.

Pulmonary Causes

- Diseases of the lung parenchyma such as tumor, interstitial pulmonary fibrosis (e.g., pneumonia, tuberculosis, asbestosis), and atelectasis
- Disorders of cardiovascular/pulmonary origin, such as pulmonary edema or pulmonary embolism
- Inadequate or abnormal pulmonary development (bronchopulmonary dysplasia)
- Advanced age

Extrapulmonary Causes

- Chest wall pain secondary to trauma or surgery
- Chest wall stiffness associated with extrapulmonary disease (e.g., scleroderma, ankylosing spondylitis)
- Postural deformities (scoliosis, kyphosis)
- Ventilatory muscle weakness of neuropathic or myopathic origin (e.g., spinal cord injury, cerebral palsy, Parkinson’s disease, muscular dystrophy)
- Pleural disease
- Insufficient diaphragmatic excursion because of ascites or obesity

Pathological Changes in the Pulmonary System

Pulmonary function may be altered as a result of pulmonary or extrapulmonary conditions. These alterations in lung volumes and capacities are depicted in Figure 25.39. Cardiopulmonary factors contributing to these changes are decreased pulmonary compliance caused by inflammation or fibrosis (thickening of the alveoli, bronchioles, or pleura), pulmonary congestion, and decreased arterial blood gases (hypoxemia).

Management Guidelines: Post-Thoracic Surgery

Although any number of acute or chronic disorders can be the underlying cause(s) of restrictive lung dysfunction, only management after thoracic surgery is addressed in this section. Patients with cardiac or pulmonary conditions that require surgical interventions are at high risk for restrictive pulmonary complications after surgery. Thoracotomy, an incision into the chest wall, is necessary during many types of pulmonary surgery including lobectomy (removal of a lobe of a lung), pneumonectomy (removal of a lung), or segmental resection (removal of a segment of a lobe of a lung). Cardiac surgeries, such as coronary artery bypass graft surgery, replacement of one or more valves of the heart, repair of septal defects, or heart transplantation also require thoracotomy.

NOTE: Patients who undergo upper abdominal surgery also have a high risk of developing postoperative pulmonary complications. Postoperative pain is often greater after upper abdominal surgery than after thoracic surgery. This results in hypoventilation (55% decreased vital capacity for the first 24 to 48 hours after surgery) and an ineffective cough, which place the patient at risk for developing pneumonia or atelectasis. A systematic review of the literature revealed that postoperative programs of cardiopulmonary physical therapy have beneficial effects after upper abdominal surgery.

Factors That Increase the Risk of Pulmonary Complications and Restrictive Lung Dysfunction After Thoracic Surgery

The post-thoracotomy patient experiences considerable chest pain, which leads to chest wall immobility, poor lung
**Impairments**

An increase in the amount and viscosity of mucus production
A chronic, often productive cough
Frequent episodes of dyspnea
A labored breathing pattern that results in:
- Increased respiratory rate (tachypnea)
- Use of accessory muscles of inspiration and decreased diaphragmatic excursion
- Upper chest breathing
Inadequate exchange of air in the lower lobes
Most difficulty during expiration; use of pursed-lip breathing
Changes in pulmonary function
- Increased residual volume
- Decreased vital capacity
- Decreased expiratory flow rates
Decreased mobility of the chest wall; a barrel chest deformity develops
Abnormal posture: forward-head and rounded and elevated shoulders
Decreased general endurance during functional activities

**Box 25.11**

**Management Guidelines—Chronic Obstructive Pulmonary Disease (COPD)**

<table>
<thead>
<tr>
<th>Plan of Care</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Decrease the amount and viscosity of secretions and prevent respiratory infections.</td>
<td>1. Administration of bronchodilators, antibiotics, and humidification therapy. If patient smokes, he or she should be strongly encouraged to stop.</td>
</tr>
<tr>
<td>2. Remove or prevent the accumulation of secretions. (This is important if emphysema is associated with chronic bronchitis or if there is an acute respiratory infection.)</td>
<td>2. Deep and effective cough. Postural drainage to areas where secretions are identified. <strong>NOTE:</strong> Drainage positions may need to be modified if the patient is dyspneic in the head-down position.</td>
</tr>
</tbody>
</table>
| 3. Promote relaxation of the accessory muscles of inspiration to decrease reliance on upper chest breathing and to decrease muscle tension associated with dyspnea. | 3. Positioning for relaxation.  
- Relaxed head-up position in bed: trunk, arms, and head are well supported.  
- Sitting: leaning forward, resting forearms on thighs or on a table.  
- Standing: leaning forward on an object, with hands on the thighs or leaning backward against a wall. Relaxation exercises for shoulder musculature: active shoulder shrugging followed by relaxation; shoulder and arm circles; horizontal abduction and adduction of the shoulders. |
| 4. Improve the patient’s breathing pattern and ventilation. Emphasize diaphragmatic and lateral costal breathing and relaxed expiration; decrease the work of breathing, rate of respiration, and use of accessory muscles. Carry over controlled breathing exercises to functional activities. | 4. Breathing exercises: controlled diaphragmatic breathing with minimal upper chest movement; lateral costal breathing; pursed-lip breathing (careful to avoid forced expiration). Practice controlled breathing during standing, walking, climbing stairs, and other functional activities. |
| 5. Minimize or prevent episodes of dyspnea. | 5. Have a patient assume a comfortable position so the upper chest is relaxed and the lower chest is as mobile as possible. Emphasize controlled diaphragmatic breathing. Have the patient breathe out as rapidly as possible without forcing expiration. **NOTE:** Initially, the rate of ventilation is rapid and shallow. As the patient gets control of breathing, he or she slows the rate. Administer supplemental oxygen during a severe episode, if needed. |
| 6. Improve the mobility of the lower thorax. | 6. Exercises for chest mobility, emphasizing movement of the lower rib cage during deep breathing. |
| 7. Improve posture. | 7. Exercises and postural training to decrease forward-head and rounded shoulders. |
| 8. Increase exercise tolerance. | 8. Graded endurance and conditioning exercises (see Chapter 4). |
expansion, and an ineffective cough. In addition, pulmonary secretions are greater than normal after surgery. Therefore, the patient is more likely to accumulate pulmonary secretions and develop secondary pneumonia or atelectasis. Factors that increase the risk of postoperative pulmonary complications are noted in the following sections.17,40

General Anesthesia
- Decreases the normal ciliary action of the tracheobronchial tree
- Depresses the respiratory center of the central nervous system, which causes a shallow respiratory pattern (decreased tidal volume and vital capacity)
- Depresses the cough reflex

Intubation (Insertion of an Endotracheal Tube)
- Causes muscle spasm and immobility of the chest
- Irritates the mucosal lining of the tracheobronchial tree, which causes increased production of mucus
- Decreases the normal action of the cilia in the tracheobronchial tree, which leads to pooling of secretions

Incisional Pain
- Causes muscle splinting and decreases chest wall compliance, which in turn causes a shallow breathing pattern. Consequently, lung expansion is restricted and secretions are not adequately mobilized.
- Restricts a deep and effective cough. The patient usually has a weak, shallow cough that does not effectively mobilize and clear secretions

Pain Medication
Although pain medication administered postoperatively diminishes incisional pain, it also:
- Depresses the respiratory center of the central nervous system
- Decreases the normal ciliary action in the bronchial tree

General Inactivity, Postoperative Weakness and Fatigue
- Pooling of secretions, particularly in the posterior basilar segments of the lower lobes, because of inactivity
- Decreased effectiveness of the cough pump because of postoperative weakness and fatigue

Other risk factors not directly related to the surgery
- Patient’s age (> age 50)
- History of smoking
- History of COPD or restrictive pulmonary disorder because of neuromuscular weakness
- Obesity
- Poor mentation and orientation

Thoracic Surgery: Operative and Postoperative Considerations during Management

Many factors contribute to a patient’s postoperative impairments, any one of which influences postoperative management.17,23 A patient who has undergone thoracotomy for a pulmonary or cardiac condition typically is hospitalized for a week or less. Postoperative impairments and guidelines for management of a patient who has undergone thoracic surgery are summarized in Box 25.12.16,17,23,36,40,41,71 Therapeutic interventions begin on the first postoperative day and include breathing and coughing exercises, shoulder ROM, posture awareness training, and a graded aerobic conditioning program.16,23,36,40,41,71

Co-morbidities and Related Dysfunction
In addition to the primary pulmonary or cardiac pathology (e.g., a malignant tumor, lung abscess, coronary artery disease) the patient also may have related cardiopulmonary conditions, such as angina, congestive heart disease, chronic bronchitis, or emphysema. The patient with a long history of cardiac disease may have preoperative pulmonary dysfunction such as hypoxemia, dyspnea on exertion, orthopnea, or pulmonary congestion. Such co-morbidities and related pulmonary or cardiac dysfunction can complicate postoperative rehabilitation.

Surgical Approach
Pulmonary surgery typically involves a large posterolateral, lateral, or anterolateral chest incision. A standard posterolateral approach (Fig. 25.40), for example, is performed by incising the chest wall along the intercostal space that corresponds to the location of the lung lesion. The incision divides the trapezius and rhomboid muscles posteriorly and the serratus anterior, latissimus dorsi, and external and internal intercostals laterally.

Postoperatively, the incision is painful, and the potential for pulmonary complications is significant. Many patients, quite understandably, complain of a great deal of shoulder soreness on the operated side. Loss of range of shoulder motion and postural deviations are possible because of the disturbance of the large arm and trunk musculature during surgery.
### Impairments
- Reduced lung expansion or an inability to take a deep inspiration because of incisional pain
- Decreased effectiveness of the cough because of incisional pain and irritation of the throat from intubation
- Possible accumulation of pulmonary secretions either preoperatively or postoperatively
- Decreased chest wall and upper extremity mobility
- Poor postural alignment because of incisional pain or chest tubes
- Increased risk of deep vein thrombosis and pulmonary embolism
- General weakness, fatigue, and disorientation

### BOX 25.12
**MANAGEMENT GUIDELINES—Post-Thoracic Surgery**

<table>
<thead>
<tr>
<th>Plan of Care</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ascertain the status of the patient before each treatment.</td>
<td>1. Evaluate orientation, color, respiratory rate, heart rate, breath sounds, sputum drainage into chest tubes.</td>
</tr>
<tr>
<td>2. Promote relaxation and reduce postoperative pain.</td>
<td>2. Position the patient in a semi-Fowler’s position (head of bed elevated to 30° and hips and knees slightly flexed). This position reduces traction on the thoracic incision. Coordinate treatment with administration of pain medication.</td>
</tr>
<tr>
<td>3. Optimize ventilation and re-expand lung tissue to prevent atelectasis and pneumonia.</td>
<td>3. Begin deep-breathing exercises on the day of surgery as soon as the patient is conscious; diaphragmatic breathing; segmental expansion. Emphasize a deep inhalation followed by a 3- to 5-second hold and then relaxed exhalation. Continue deep-breathing exercises postoperatively, with six to ten consecutive deep breaths per hour until the patient is ambulatory.</td>
</tr>
<tr>
<td>4. Assist in the removal of secretions.</td>
<td>4. Begin deep, effective coughing as soon as the patient is alert and can cooperate. Implement early functional mobility (getting up to a chair, early ambulation). Institute modified postural drainage only if secretions accumulate.</td>
</tr>
<tr>
<td>5. Maintain adequate circulation in the lower extremities to prevent deep vein thrombosis and pulmonary embolism.</td>
<td>5. Begin active exercises of the lower extremities, with emphasis on ankle pumping exercises on the first day after surgery. Continue leg exercises until the patient is allowed out of bed and is ambulatory.</td>
</tr>
<tr>
<td>6. Regain ROM in the shoulders.</td>
<td>6. Begin relaxation exercises for the shoulder area on the first postoperative day. These can include shoulder shrugging or shoulder circles. Initiate active-assistive ROM of the shoulders, being careful not to cause pain. Reassure the patient that gentle movements will not disturb the incision. Progress to active shoulder exercises on the succeeding postoperative days to the patient’s tolerance until full active ROM has been achieved.</td>
</tr>
<tr>
<td>7. Prevent postural impairments.</td>
<td>7. Reinforce symmetrical alignment and positioning of the trunk on the first postoperative day when the patient is in bed. <strong>NOTE:</strong> The patient will tend to lean toward the side of the incision. Instruct the patient in symmetrical sitting posture when he or she is allowed to sit up in a chair or at the side of the bed.</td>
</tr>
<tr>
<td>8. Increase exercise tolerance.</td>
<td>8. Begin a progressive and graded ambulation or stationary cycling program as soon as the chest tubes are removed and the patient is allowed out of bed.</td>
</tr>
</tbody>
</table>

### Precautions
- Monitor vital signs throughout treatment.
- Be certain to show the patient how to splint over the incision to minimize incisional pain during coughing.
- Avoid placing traction on chest tubes when moving the patient.
- To prevent dislodging a chest tube for the patient who has a lateral incision, limit shoulder flexion to 90° on the operated side for several days until the chest tube is removed.
- If postural drainage must be implemented, modify positioning to avoid a head-down position.
- Do not use percussion over the incision.
- When turning a patient, use a logroll technique to minimize traction on the incision.
The most common incision used with cardiac surgery is a **median sternotomy.** A large incision extends along the anterior chest from the sternal notch to just below the xiphoid. The sternum is then split and retracted so the chest cavity can be exposed. After completion of the surgical procedure, the sternum is closed with stainless steel sutures. Postoperatively, there is less incisional pain after a median sternotomy than after a posterolateral thoracotomy, but deep breathing and coughing are still painful. After a median sternotomy, a patient tends to exhibit rounded shoulders and is at risk for developing shortened pectoralis muscles bilaterally.

**Additional Considerations**

After any type of thoracotomy one or two chest drainage tubes are put in place at the time of the surgery to prevent a *pneumothorax* or a *hemothorax.* While these tubes are in place, crimping, clamping, or traction on the tubes must be avoided during postoperative interventions.

Fatigue occurs easily during the first few postoperative days, so treatment sessions should be short but frequent. The duration of treatment should be increased gradually during the patient’s hospital stay.

Check the patient’s chart regularly to note any day-to-day changes in vital signs or laboratory test results. Always monitor vital signs such as heart rate and rhythm, respiratory rate, and blood pressure prior to, during, and after every treatment session.
cough is currently nonproductive, he has had a chronic cough for years. He has also smoked more than a pack of cigarettes a day for 35 years. He is currently febrile with a 99.8°F temperature.

- What current and potential postoperative impairments might you find in your examination?
- Design a comprehensive management program that includes airway clearance, exercise, and functional mobility. How would you progress the program while the patient is hospitalized? What precautions should be built into his plan of care?
- Design a program that the patient can follow when he returns home.

**CASE 2**

B.A. is a 21-year-old student with a 15-year history of asthma. Her chief complaint is episodes of dyspnea when she is physically active. She wheezes frequently, particularly with physical activity but sometimes at rest. Wheezing also is worse when in contact with household pets at friends’ apartments. She is small for her age and underweight but wants to participate in some form of regular physical activity for general health and fitness. What additional signs or symptoms would you expect to find in an examination of this young woman? How would you manage her problems and needs?

**REFERENCES**

36. Hillegass, EA, Sadowsky, HS: Cardiovascular and thoracic interventions. In Hillegass, EA, Sadowsky, HS (eds) Essentials of Cardiopul-