8.2: Oxygenation Basic Concepts

Several body systems contribute to a person’s oxygenation status, including the respiratory, cardiovascular, and hematological systems. These systems are reviewed in the following sections.

Respiratory System

The main function of our respiratory system is to provide the body with a constant supply of oxygen and to remove carbon dioxide. To achieve these functions, muscles and structures of the thorax create the mechanical movement of air into and out of the lungs called ventilation. Gas exchange occurs at the alveolar level where blood is oxygenated and carbon dioxide is removed, which is called respiration. Several respiratory conditions can affect a patient’s ability to maintain adequate ventilation and respiration, and there are several medications used to enhance a patient’s oxygenation status. Use the following hyperlinks to review information regarding the anatomy and physiology of the respiratory system, common respiratory conditions, and classes of respiratory medications.

Note

Read additional information about the “Respiratory System” in Open RN Nursing Pharmacology or use the following hyperlinks to go to specific subsections of the chapter:

- Review the anatomy and physiology of the respiratory system.
- Learn about common respiratory disorders.
- Read about common respiratory medications.
Cardiovascular System

In order for oxygenated blood to move from the alveoli in the lungs to the various organs and tissues of the body, the heart must adequately pump blood through the systemic arteries. The amount of blood that the heart pumps in one minute is referred to as **cardiac output**. The passage of blood through arteries to an organ or tissue is referred to as **perfusion**. Several cardiac conditions can adversely affect cardiac output and perfusion in the body. There are several medications used to enhance a patient’s cardiac output and maintain adequate perfusion to organs and tissues throughout the body. Use the following hyperlinks to review information regarding the anatomy and physiology of the cardiovascular system, common cardiac disorders, and various cardiovascular system medications.

**Note**

Read additional information about the cardiovascular system in the “**Cardiovascular & Renal**" chapter in Open RN *Nursing Pharmacology* or use the following hyperlinks to go to specific subsections of this chapter:

- Review the [anatomy and physiology](#) of the cardiovascular system.
- Learn about [common cardiac disorders](#).
- Read about common [cardiovascular system medications](#).

Hematological System

Although the bloodstream carries small amounts of dissolved oxygen, the majority of oxygen molecules are transported throughout the body by attaching to hemoglobin within red blood cells. Each hemoglobin protein is capable of carrying four oxygen molecules. When all four hemoglobin structures contain an oxygen molecule, it is referred to as “saturated.” See Figure 8.1 for an image of hemoglobin protein within a red blood cell with four sites for carrying oxygen molecules.
When oxygenated blood reaches tissues within the body, oxygen is released from the hemoglobin, and carbon dioxide is picked up and transported to the lungs for release on exhalation. Carbon dioxide is transported throughout the body by three major mechanisms: dissolved carbon dioxide, attachment to water as HCO₃⁻, and attachment to the hemoglobin in red blood cells. — See Figure 8.2 for an illustration of carbon dioxide transport.

![Figure 8.2 Carbon Dioxide Transport](image)

**Measuring Oxygen, Carbon Dioxide, and Acid Base Levels**

Because the majority of oxygen transported in the blood is attached to hemoglobin, a patient’s oxygenation status is easily assessed using pulse oximetry, referred to as SpO₂. See Figure 8.3 for an image of a pulse oximeter. This reading refers to the amount of hemoglobin that is saturated. The target range of SpO₂ for an adult is 94-98%. — For patients with chronic oxygenation conditions such as COPD, the target range for SpO₂ is often lower at 88% to 92%. Although SpO₂ is an efficient, noninvasive method for assessing a patient’s oxygenation status, it is not always accurate. For example, if a patient is severely anemic, the patient has a decreased amount of hemoglobin in the blood.
available to carry the oxygen, which subsequently affects the SpO2 reading. Decreased perfusion of the extremities can also cause inaccurate SpO2 levels because less blood delivered to the tissues causes a false low SpO2. Additionally, other substances can attach to hemoglobin such as carbon monoxide, causing a falsely elevated SpO2.

A more specific measurement of oxygen and carbon dioxide in the blood is obtained using an arterial blood gas (ABG). ABG results are often used for patients who have deteriorating or unstable respiratory status requiring emergency treatment. An ABG is a blood sample that is typically drawn from the radial artery by a respiratory therapist. ABG results indicate oxygen, carbon dioxide, pH, and bicarbonate levels. The partial pressure of oxygen in the arterial blood is referred to as PaO2. PaO2 measures the pressure of oxygen dissolved in the arterial blood and how well oxygen is able to move from the lungs into the blood. The normal PaO2 level of a healthy adult is 80 to 100 mmHg. The PaO2 reading is more accurate than a SpO2 reading because it is not affected by hemoglobin levels. The partial pressure of carbon dioxide in the arterial blood is the PaCO2 level. The PaCO2 level measures the pressure of carbon dioxide dissolved in the blood and how well carbon dioxide is able to move out of the body. It is typically used to determine if sufficient ventilation is occurring at the alveolar level. The normal PaCO2 level of a healthy adult is 35-45 mmHg. The normal range of pH level for arterial blood is 7.35-7.45, and the normal range for the bicarbonate (HCO3-) level is 22-26. The SaO2 level is also calculated in ABG results, which is the calculated arterial oxygen saturation level.\[8\]

**Hypoxia and Hypercapnia**

**Hypoxia** is defined as a reduced level of tissue oxygenation. Hypoxia has many causes, ranging from respiratory and cardiac conditions to anemia. **Hypoxemia** is a specific type of hypoxia that is defined as decreased partial pressure of oxygen in the blood (PaO2) indicated in an arterial blood gas (ABG) result.

Early signs of hypoxia are anxiety, confusion, and restlessness. As hypoxia worsens, the patient’s level of consciousness and vital signs will worsen with an increased respiratory rate and heart rate and decreased pulse oximetry readings. Late signs of hypoxia include bluish discoloration of the skin and mucous membranes called cyanosis. See Figure 8.4\[9\] for an image of cyanosis.
Hypercapnia, also referred to as hypercarbia, is an elevated level of carbon dioxide in the blood. This level is measured by the PaCO2 level in an ABG test and is indicated when the PaCO2 level is greater than 45. Hypercapnia is caused by hypoventilation or when the alveoli are ventilated but not perfused. In a state of hypercapnia, the accumulation of carbon dioxide in the blood causes the pH of the blood to drop, leading to a state of respiratory acidosis. You can read more about respiratory acidosis in the “Acid-Base Balance” section of the “Fluids and Electrolytes” chapter. Patients with hypercapnia have symptoms such as tachycardia, dyspnea, flushed skin, confusion, headaches, and dizziness. If the hypercapnia develops gradually over time, symptoms may be mild or may not be present at all. Hypercapnia is managed by addressing its underlying cause. A noninvasive positive pressure device such as a BiPAP may be used to help eliminate the excess carbon dioxide, but if this is not sufficient, intubation may be required. You can read more about BiPAP devices and intubation in the “Oxygen Therapy” chapter in Open RN Nursing Skills.

It is important for a nurse to recognize early signs of respiratory distress and report changes in patient condition to prevent respiratory failure. See Table 8.2a for symptoms and signs of respiratory distress.

<table>
<thead>
<tr>
<th>Signs and Symptoms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortness of breath (Dyspnea)</td>
<td>Dyspnea is a subjective symptom of not getting enough air. Depending on severity, dyspnea causes increased levels of anxiety.</td>
</tr>
<tr>
<td>Restlessness</td>
<td>An early sign of hypoxia.</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>An elevated heart rate (above 100 beats per minute in adults) can be an early sign of hypoxia.</td>
</tr>
<tr>
<td>Tachypnea</td>
<td>An increased respiration rate (above 20 breaths per minute in adults) is an indication of respiratory distress.</td>
</tr>
<tr>
<td>Oxygen saturation level</td>
<td>Oxygen saturation levels should be above 94% for an adult without an underlying respiratory condition.</td>
</tr>
<tr>
<td>(SpO2)</td>
<td>Use of accessory muscles</td>
</tr>
<tr>
<td>------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Noisy breathing</td>
<td></td>
</tr>
<tr>
<td>Flaring of nostrils</td>
<td></td>
</tr>
<tr>
<td>Skin color (Cyanosis)</td>
<td></td>
</tr>
<tr>
<td>Position of patient</td>
<td></td>
</tr>
<tr>
<td>Ability of patient to speak in full sentences</td>
<td></td>
</tr>
<tr>
<td>Confusion or change in level of consciousness (LOC)</td>
<td></td>
</tr>
</tbody>
</table>

### Treating Hypoxia and Hypercapnia

Hypoxia and/or hypercapnia are medical emergencies and should be treated promptly by calling for assistance as indicated by agency policy.

Failure to initiate oxygen therapy when needed can result in serious harm or death of the patient. Although oxygen is considered a medication that requires a prescription, oxygen therapy may be initiated without a physician’s order in emergency situations as part of the nurse’s response to the “ABCs,” a common abbreviation for airway, breathing, and circulation. Most agencies have a protocol in place that allows nurses to apply oxygen in emergency situations and obtain the necessary order at a later time.  

In addition to administering oxygen therapy, there are several other interventions a nurse can implement to assist an hypoxic patient. Additional interventions used to treat hypoxia in conjunction with oxygen therapy are outlined in Table 8.2b.
<table>
<thead>
<tr>
<th>Interventions</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raise the head of the bed.</td>
<td>Raising the head of the bed to high Fowler’s position promotes effective chest expansion and diaphragmatic descent, maximizes inhalation, and decreases the work of breathing.</td>
</tr>
<tr>
<td>Use tripod positioning.</td>
<td>Situate the patient in a tripod position. Patients who are short of breath may gain relief by sitting upright and leaning over a bedside table while in bed, which is called a three-point or tripod position.</td>
</tr>
<tr>
<td>Encourage enhanced breathing and coughing techniques.</td>
<td>Enhanced breathing and coughing techniques such as using pursed-lip breathing, coughing and deep breathing, huffing technique, incentive spirometry, and flutter valves may assist patients to clear their airway while maintaining their oxygen levels. See the “Enhanced Breathing and Coughing Techniques” section below for additional information regarding these techniques.</td>
</tr>
<tr>
<td>Manage oxygen therapy and equipment.</td>
<td>If the patient is already on supplemental oxygen, ensure the equipment is turned on, set at the required flow rate, and is properly connected to an oxygen supply source. If a portable tank is being used, check the oxygen level in the tank. Ensure the connecting oxygen tubing is not kinked, which could obstruct the flow of oxygen. Feel for the flow of oxygen from the exit ports on the oxygen equipment. In hospitals where medical air and oxygen are used, ensure the patient is connected to the oxygen flow port.</td>
</tr>
<tr>
<td>Assess the need for respiratory medications.</td>
<td>Various types of oxygenation equipment are prescribed for patients requiring oxygen therapy. Oxygenation equipment is typically managed in collaboration with a respiratory therapist in hospital settings. Equipment includes devices such as nasal cannula, masks, Continuous Positive Airway Pressure (CPAP), Bilevel Positive Airway Pressure (BiPAP), and mechanical ventilators. For more information, see the “Oxygenation Equipment” section of the “Oxygen Therapy” chapter in Open RN Nursing Skills.</td>
</tr>
<tr>
<td>Provide succioning, if needed.</td>
<td>Pharmacological management is essential for patients with respiratory disease such as asthma, COPD, or severe allergic response. Bronchodilators effectively relax smooth muscles and open airways. Glucocorticoids relieve inflammation and also assist in opening air passages. Mucolytics decrease the thickness of pulmonary secretions so that they can be expectorated more easily.</td>
</tr>
<tr>
<td>Provide pain relief, if needed.</td>
<td>Some patients may have a weakened cough that inhibits their ability to clear secretions from the mouth and throat. Patients with muscle disorders or those who have experienced a stroke (i.e., cerebral vascular accident) are at risk for aspiration, which could lead to pneumonia and hypoxia. Provide oral suction if the patient is unable to clear secretions from the mouth and pharynx. See the “Tracheostomy Care and Suctioning” chapter in Open RN Nursing Skills for additional details on suctioning.</td>
</tr>
<tr>
<td>Consider side effects</td>
<td>Provide adequate pain relief if the patient is reporting pain. Pain increases anxiety and metabolic demands, which, in turn, increase the need for more oxygen supply.</td>
</tr>
<tr>
<td></td>
<td>A common side effect of pain medication is respiratory depression. For more information about managing respiratory depression, see the “Pain Management” section of the “Comfort” chapter.</td>
</tr>
</tbody>
</table>
of pain medication.

Consider other devices to enhance clearance of secretions.

Chest physiotherapy and specialized devices assist with secretion clearance, such as handheld flutter valves or vests that inflate and vibrate the chest wall. Consult with a respiratory therapist as needed based on the patient’s situation.

Plan frequent rest periods between activities.

Plan interventions for patients with dyspnea so they can rest frequently and decrease oxygen demand.

Consider other potential causes of dyspnea.

If a patient’s level of dyspnea is worsening, assess for other underlying causes in addition to the primary diagnosis. For example, are there other respiratory, cardiovascular, or hematological conditions occurring? Start by reviewing the patient’s most recent hemoglobin and hematocrit lab results, as well as any other diagnostic tests such as chest X-rays and ABG results. Completing a thorough assessment may reveal abnormalities in these systems to report to the health care provider.

Consider obstructive sleep apnea.

Patients with obstructive sleep apnea (OSA) are often not previously diagnosed prior to hospitalization. The nurse may notice the patient snores, has pauses in breathing while snoring, has decreased oxygen saturation levels while sleeping, or awakens feeling not rested. These signs may indicate the patient is unable to maintain an open airway while sleeping, resulting in periods of apnea and hypoxia. If these apneic periods are noticed but have not been previously documented, the nurse should report these findings to the health care provider for further testing and follow-up. A prescription for a CPAP or BiPAP device while sleeping may be needed to prevent adverse outcomes.

Monitor patient’s anxiety.

Assess patient’s anxiety. Anxiety often accompanies the feeling of dyspnea and can worsen it. Anxiety in patients with COPD is chronically undertreated. It is important for the nurse to address the feelings of anxiety in addition to the feelings of dyspnea. Anxiety can be relieved by teaching enhanced breathing and coughing techniques, encouraging relaxation techniques, or administering antianxiety medications.

Enhanced Breathing and Coughing Techniques

In addition to oxygen therapy and the interventions listed in Table 8.2b, there are several techniques a nurse can teach a patient to use to enhance their breathing and coughing. These techniques include pursed-lip breathing, incentive spirometry, coughing and deep breathing, and the huffing technique. Additionally, vibratory positive expiratory pressure (PEP) therapy can be incorporated in collaboration with a respiratory therapist.

Pursed-lip Breathing

Pursed-lip breathing is a technique that decreases dyspnea by teaching people to control their oxygenation and
ventilation. See Figure 8.5[^13] for an illustration of pursed-lip breathing. The technique teaches a person to inhale through the nose and exhale through the mouth at a slow, controlled flow. This type of exhalation gives the person a puckered or pursed-lip appearance. By prolonging the expiratory phase of respiration, a small amount of positive end-expiratory pressure (PEEP) is created in the airways that helps to keep them open so that more air can be exhaled. This subsequently reduces air trapping that commonly occurs in conditions such as chronic obstructive pulmonary disease (COPD). Pursed-lip breathing relieves the feeling of shortness of breath, decreases the work of breathing, and improves gas exchange. People also regain a sense of control over their breathing while simultaneously increasing their relaxation.[^14]

![Figure 8.5 Pursed-Lip Breathing](https://med.libretexts.org/Bookshelves/Nursing/Nursing_Fundamentals_(OpenRN)/08%3A_Oxygenation/8.02%3A_Oxygenati...)

**Incentive Spirometry**

An *incentive spirometer* is a medical device commonly prescribed after surgery to expand the lungs, reduce the buildup of fluid in the lungs, and prevent pneumonia. See Figure 8.6[^15] for an image of a patient using an incentive spirometer. While sitting upright, if possible, the patient should place the mouthpiece in their mouth and create a tight seal with their lips around it. They should breathe in slowly and as deeply as possible through the tubing with the goal of raising the piston to their prescribed level. The resistance indicator on the right side should be monitored to ensure they are not breathing in too quickly. The patient should attempt to hold their breath for as long as possible (at least 5 seconds) and then exhale and rest for a few seconds. Coughing is expected. Encourage the patient to expel the mucus and not swallow it. This technique should be repeated by the patient 10 times every hour while awake.[^16] The nurse may delegate this intervention to unlicensed assistive personnel, but the frequency in which it is completed and the volume achieved should be documented and monitored by the nurse.
Using an incentive spirometer can feel monotonous to patients, resulting in the lack of performing this important activity to prevent pneumonia. It is helpful to encourage patients to create easy reminders to complete the activity. For example, many patients watch television. Create the reminder to use the incentive spirometer each time they view a commercial. This is a helpful trigger to use the incentive spirometer frequently.

**Coughing and Deep Breathing**

**Coughing and deep breathing** is a breathing technique similar to incentive spirometry but no device is required. The patient is encouraged to take deep, slow breaths and then exhale slowly. After each set of breaths, the patient should cough. This technique is repeated 3 to 5 times every hour.

**Huffing Technique**

The **huffing technique** is helpful to teach patients who have difficulty coughing. Teach the patient to inhale with a medium-sized breath and then make a sound like “ha” to push the air out quickly with the mouth slightly open.

**Vibratory PEP Therapy**

**Vibratory Positive Expiratory Pressure (PEP) Therapy** uses handheld devices such as flutter valves or Acapella devices for patients who need assistance in clearing mucus from their airways. These devices require a prescription and
are used in collaboration with a respiratory therapist or advanced health care provider. To use vibratory PEP therapy, the patient should sit up, take a deep breath, and blow into the device. A flutter valve within the device creates vibrations that help break up the mucus so the patient can cough and spit it out. Additionally, a small amount of positive end-expiratory pressure (PEEP) is created in the airways that helps to keep them open so that more air can be exhaled. See the supplementary video below regarding how to use the flutter valve device.

Note

View this video on Using a Flutter Valve Device (Acapella).[17]