5.2: Principles

The air we breathe is made up of various gases, 21% of which is oxygen. Therefore, a patient who is receiving no supplemental oxygen therapy is still receiving oxygen from the air. This amount of oxygen is adequate provided that the patient’s airway is not compromised and there is sufficient hemoglobin in the blood. The cardiovascular system must also be intact and able to circulate blood to all body tissues. If any of these systems fail, the patient will require supplemental oxygen to increase the likelihood that adequate levels of oxygen will reach all vital body tissues necessary to sustain life.

Oxygen in the Blood

Hemoglobin (Hgb) holds oxygen in reserve until the metabolic demands of the body require more oxygen. The Hgb then moves the oxygen to the plasma for transport to the tissues. The body’s demand for oxygen is affected by activity, metabolic status, temperature, and level of anxiety. The ability of Hgb to move the oxygen to the tissues depends on a number of factors, such as oxygen supply, ventilatory effectiveness, nutrition, cardiac output, hemoglobin level, smoking, drug use, and underlying disease. Any one of these factors can potentially impede the supply and transport of oxygen to the tissues.

Measurement of Oxygen in the Blood

The vast majority of oxygen carried in the blood is attached to hemoglobin and can be assessed by monitoring the oxygen saturation through pulse oximetry (SpO₂). The target range for oxygen saturation as measured by blood analysis (SaO₂), such as arterial blood gas, is 92% to 98% for a normal adult. Arterial blood gas (ABG) is the analysis of an arterial blood sample to evaluate the adequacy of ventilation, oxygen delivery to the tissues, and acid-base balance status (Simpson, 2004). For patients with COPD, the target SaO₂ range is 88% to 92% (Alberta Health Services, 2015;...
British Thoracic Society, 2008; Kane et al., 2013). Only about 3% of the oxygen carried in the blood is dissolved in the plasma, which can be assessed by looking at the partial pressure of oxygen in the blood through blood gas analysis (PaO$_2$). The normal PaO$_2$ of a healthy adult is 80 to 100 mmHg. The SpO$_2$ is more clinically significant than the PaO$_2$ in determining the oxygen content of the blood.

Oxygen is considered a medication and therefore requires continuous monitoring of the dose, concentration, and side effects to ensure its safe and effective use (Alberta Health Services, 2015). Oxygen therapy may be indicated for hypoxemia and hypoxia.

### Understanding Hypoxemia and Hypoxia

Although the terms hypoxemia and hypoxia are often used interchangeably, they do not mean the same thing. **Hypoxemia** is a condition where arterial oxygen tension or partial pressure of oxygen (PaO$_2$) is below normal (<80 mmHg). Hypoxemia is the inadequate supply of oxygen in the arterial blood. **Hypoxia** is the reduction of oxygen supply at the tissue level, which is not measured directly by a laboratory value (Metrovic, 2014), but by pulse oximetry and SpO$_2$ (British Thoracic Society, 2008).

Generally, the presence of hypoxemia suggests that hypoxia exists. However, hypoxia may not be present in a patient with hypoxemia if the patient is able to compensate for a low PaO$_2$ by increasing oxygen supply. This is usually achieved by increasing cardiac output (by raising the heart rate) or by decreasing tissue oxygen consumption. Conversely, patients who do not show signs of hypoxemia may be hypoxic if oxygen delivery to the tissues is diminished or if the tissues are unable to adequately use the oxygen.

Hypoxemia is the most common cause of tissue hypoxia, and if the correct diagnosis is made, it is readily treatable.

The Vancouver Coastal Health Authority (2015) lists three causes of hypoxemia: deadspace and shunts, low inspired oxygen tension, and alveolar hypoventilation.

### Deadspace and Shunts

Ventilation and perfusion are not always equal between the alveoli and pulmonary capillaries. There is sometimes too much perfusion and not enough ventilation in some areas of the lungs, causing a shunt where the blood is unable to pick up oxygen and unload carbon dioxide. In other areas of the lungs, there may be too much ventilation and not enough perfusion, causing deadspace where oxygen is unable to diffuse into the blood.

### Low Inspired Oxygen Tension

Hypoxemia can be caused by breathing air at pressures less than atmospheric pressure, such as at high altitudes or in an enclosed space with inadequate ventilation. The enclosed space may be especially hazardous if there is a low concentration of oxygen or if it contains toxic gases.

### Alveolar Hypoventilation

If a patient hypoventilates, the level of oxygen in the alveoli will fall, and the level of carbon dioxide will increase.
Hypoxemia occurs because less oxygen is moved into the pulmonary blood flow.

Examples of medical conditions that cause hypoxemia include:

- Asthma
- COPD
- Heart failure
- Pleural effusions
- Pneumonia
- Pneumothorax
- Pulmonary edema
- Pulmonary emboli

With hypoxia, there is inadequate transport of oxygen to the cells or tissues, either because of obstruction, secretions, or tumours in the lungs; hypoventilation due to disease, injury to the respiratory system, or medications; or poor blood flow due to a compromised circulatory system (British Thoracic Society, 2008). Hypoxia related to anemia or circulatory system compromise, such as decreased cardiac output, will respond poorly to oxygen therapy, and other appropriate interventions should be considered.

Hypoxia is a medical emergency (Alberta Health Services, 2015). Oxygen therapy will:

- Decrease the work of breathing in patients with respiratory or cardiovascular conditions, which may prevent respiratory and muscle fatigue (Jardins & Burton, 2011).
- Decrease cardiopulmonary workload by reducing high cardiopulmonary demand (Perry et al., 2014). For example, patients with left ventricular failure benefit from additional oxygen to the tissues because the heart cannot provide enough oxygen to the tissues due to decreased cardiac output.
- Support post-operative recovery, and may be ordered for a specific time frame at a specific rate while the patient recovers from the surgical procedure.

Critical Thinking Exercises

1. How do you know if your patient is hypoxic or hypoxemic? Please explain.
2. Why would the post-surgical patient require supplemental oxygen?