Experiment HC-6: Effects of Temperature on Peripheral Oxygen Saturation Levels

Background

Blood

Blood is the most vital fluid of all the different types in the body. It is responsible for the exchange of oxygen (O_2) and carbon dioxide (CO_2) between the lungs and tissues, the delivery of nutrients, the removal of waste products from the body, fighting infections, and many other important functions. One of the most important characteristics of blood, which is its ability to carry oxygen, is accomplished by the attachment of oxygen to the heme group of the hemoglobin molecule in the red blood cells. The ability of hemoglobin to carry oxygen is dependent upon the partial pressure of oxygen in air. At low partial pressures of oxygen (PO_2), like 10mmHg, only about 10% of the hemoglobin molecules are saturated with oxygen. As the partial pressure of oxygen increases, the percentage of hemoglobin molecules saturated with oxygen also increases. At a partial pressure around 60 mmHg, almost 90% of the hemoglobin molecules are saturated with oxygen. According to the oxygen-hemoglobin dissociation curve, the last 10% change in oxygen saturation from 90 to 100% requires about a 40mmHg change in the partial pressure of oxygen, from about 60mmHg to 100mmHg. The term used to express the percentage of hemoglobin that is carrying oxygen is blood oxygen saturation level (SO_2), which can be measured with devices like a blood gas analyzer or a pulse oximeter.

In the arterial system, it is expected that the oxygen saturation level of blood (SaO_2) is higher than the oxygen saturation levels in the venous system (SvO_2). Normally, blood in the arterial system is richer in oxygen than the blood in the venous system because arterial blood is carrying oxygen from its source, the lungs, to the sites of utilization, the tissues. Even at SaO_2 values between 80 and 90%, a person would be suffering from hypoxemia, which is an abnormal deficiency of oxygen in arterial blood and a condition that should not be confused with hypoxia.

There are a variety of medical conditions that can cause hypoxemia. One of these conditions is hypothermia in which the core body temperature drops below the normal range of temperatures needed for optimal body functioning. One of the reasons that make hypothermia so dangerous is the fact that cold liquids do not hold onto dissolved gases as well as warm liquids. If the liquid is blood, the oxygen saturation level of blood drops as it cools because oxygen molecules more readily dissociate from hemoglobin. Extremities that are cold also have a decreased flow of blood due to vasoconstriction. Vasoconstriction permits the conservation of heat in the core of the body, but decreases the amount of oxygen available to tissues and leads to the production of lactic acid in those tissues.

Pulse Oximetry

In clinical or training situations, an easy, non-invasive method can be used to determine the amount of oxygen in a person’s blood indirectly. This method is known as pulse oximetry and the most common type of pulse oximeter measures the oxygen saturation (SpO_2) of hemoglobin in the subject’s blood.

Pulse oximeters that measure oxygen saturation do so by measuring the absorbance of light by hemoglobin with a sensor clipped over a fingertip or on an earlobe. The sensor emits two different wavelengths of light, one in the red and the other in the infrared portion of the spectrum, and detects the absorbance of those wavelengths by the oxygenated and deoxygenated forms of hemoglobin in the blood. The absorbance at each wavelength depends on the saturation or desaturation of hemoglobin. Since one form of hemoglobin absorbs more light at a specific wavelength than the other form, the pulse oximeter can determine the ratio between the concentrations of the oxygenated and deoxygenated hemoglobin and expresses the level of oxygen in the blood as the percentage of oxygen saturation.

Pulse oximeters provide good preliminary information about the blood's oxygen saturation levels; but there are limitations with using a pulse oximeter on the peripheral circulatory system. Pulse oximeters can be highly susceptible to error when there is a change in the blood flow to the area where the sensor is applied and a change in the temperature. For example, during hypothermia, the body's natural response is to conserve the temperature of the core vital organs when heat is drawn away from the body. Two primary homeostatic mechanisms come into play in this situation: basal metabolism increases to increase heat production; and, and the flow of warm blood to distant colder parts of the body decreases. When these two mechanisms are combined, the body is able to withstand the negative effects of a cold environment for a greater period of time. However, the blood loses some of its O_2 carrying capacity and using a pulse oximeter to measure blood oxygen saturation levels from the peripheral circulation would lead to improper measurements. Definitive determinations of oxygen saturation levels in blood during conditions like hypothermia are best preformed using a blood gas analyzer.

In this experiment, students will use a pulse oximeter to measure the oxygen saturation level of the blood in the subject's middle finger. The blood saturation levels in the subject's finger will be measured before, during, and after the subject's arm is chilled. When the subject's peripheral circulation is chilled, the blood in the chilled arm should have a lower saturation level because less oxygen is attached to the hemoglobin molecules. As the red blood cells pass the sensor of the pulse oximeter, the oxygen saturation level of the blood should indicate that the cells are depleted of more oxygen than red blood cells in warmer parts of the body. In a converse exercise, students will also examine the effects of warming the arm on the blood saturation level.