Blood Oxygen Content

Oxygen delivery to the tissues is essential for life. It is dependent upon:

- Cardiac output.

- Oxygen content of the blood

Oxygen content: Amount of oxygen per unit volume of blood.
The amount of dissolved oxygen + hemoglobin-bound oxygen
Dissolved Oxygen
Dissolved oxygen is "free" within the blood and can easily diffuse out of the vessel into the tissues (for example, recall that oxygen rapidly diffuses from the pulmonary capillaries to the alveoli in the lungs). Dissolved O2 is 2% of the total oxygen content; it contributes to partial pressure, and therefore, drives diffusion. Typically, the concentration of dissolved oxygen is ~ 0.3 mL of oxygen per 100 mL of blood
Hemoglobin:
Given that the average rate of oxygen consumption in a person at rest is ~ 250 mL of oxygen per minute, the tissues cannot rely on dissolved oxygen, alone. Thus, additional oxygen must be held within the body, but also readily available to the tissues. Hemoglobin solves this problem by reversibly binding oxygen and delivering it in the bloodstream to the tissues. !hemoglobin
Hb-Bound O2
Hemoglobin is a globular protein, which comprises four subunits, each of which can bind a single oxygen molecule. Can bind up to four total oxygen molecules, but can be bound to fewer. Hemoglobin-bound oxygen comprises 98% of the total oxygen content; thus, it is a major contributor to total oxygen content and delivery. The amount of Hb-O2 is determined by two variables:

- The percentage of saturation

- The oxygen-binding capacity of hemoglobin present in the blood

Saturation percentage
Refers to the percentage of hemoglobin subunits bound to oxygen; hemoglobin bound to two oxygen molecules is 50% saturated, and Hb bound to four oxygen molecules is 100% saturated. Oxygen partial pressure determines the saturation percentage
Oxyhemoglobin dissociation curve
Sigmoid curve demonstrates how hemoglobin saturation changes in response to increasing partial pressure of oxygen. Steep portion of the curve is due to positive cooperative binding: each time hemoglobin binds an oxygen molecule, its affinity for oxygen increases. It's as if hemoglobin is offered potato chips; after it gets one, it "craves" more. Healthy systemic arterial blood is nearly 100% saturated. "P 50" reflects the partial pressure value at which hemoglobin reaches 50% saturation. Left & Right Shifts: If the curve shifts left or right, the P 50 will change to reflect hemoglobin's altered affinity for oxygen. These changes can be predicted, as follows:

- Factors that shift the curve to the right decrease hemoglobin's affinity for oxygen, and increase the P50 value; in other words, hemoglobin readily releases oxygen at lower partial pressures.

- Factors that cause a leftward shift have the opposite effects: affinity is increased, and the P50 value decreases.

Some common causes of shifts include:

- Bohr Effect: Increases in carbon dioxide and subsequent decreases in pH are shift the curve to the right; this phenomenon, called the Bohr effect, ensures that oxygen delivery meets tissue demand.

!Bohr Effect

- Alternatively, a decrease in carbon dioxide and increase in pH will increase affinity; this conserves oxygen when demand is low.

- Increased body temperature, such as during strenuous activity, oxygen release is made easier, and, vice versa.

- Increased altitude induces hypoxia, which decreases hemoglobin's affinity for oxygen to ensure oxygen release to the tissues, and,

Fetal hemoglobin (Hemoglobin F) causes a leftward shift; increased affinity facilitates oxygen loading from the maternal blood supply, despite very low placental partial pressure oxygen levels.

Oxygen-binding capacity

This is the second variable needed to calculate the amount of oxygen-bound hemoglobin. Oxygen-binding capacity is the maximum amount of oxygen bound to hemoglobin at 100% saturation. It depends upon two variables: hemoglobin concentration and hemoglobin's capacity to bind oxygen. Standard values:

- Hemoglobin concentration is 15 g/100 mL

- 1 gram of hemoglobin A, the adult form, can bind 1.34 mL of oxygen.

So, typical oxygen-binding capacity: 15 grams/100 mL * 1.34 mL oxygen = 20.1 mL/oxygen per 100 mL blood; Now, we can say that with oxygen saturation at 100%, the total amount of oxygen-bound hemoglobin is 20.1 mL of oxygen per 100 mL of blood.

Equation for total oxygen content:

Amount of dissolved oxygen equals 0.3 mL oxygen/100 milliliters of blood Amount of hemoglobin-bound oxygen is 20.1 mL oxygen/100 milliliters of blood Total oxygen content of blood is 20.4 mL oxygen per 100 milliliters of blood !oxygen content of blood Keep in mind that the values given here are for reference; physiological and pathological variations will alter the total oxygen content of blood, and, therefore, its delivery to the tissues.