

Overview of the Problem of Diving With Anemia

Anemia and Diving

DEFINITION of ANEMIA

Anemia can be defined as a reduction in the hemoglobin, hematocrit or red cell number. In physiologic terms an anemia is any disorder in which the patient suffers from tissue hypoxia due to decreased oxygen carrying capacity of the blood. It is therefore possible for a patient to be physiologically anemic and still have a normal or even raised hemoglobin, hematocrit and or red cell number, this is referred to as a relative anemia. We usually use the term “anemia” to refer to an absolute anemia, ie a reduction in red cell or hemoglobin mass.

PHYSIOLOGIC EFFECTS of ANEMIA

How the anemia effects the diver depends upon the speed at which the anemia progresses. In an acute hemorrhage the arterial pressure falls, cardiac output decreases, peripheral vasculature collapses and the patient rapidly goes into shock simply due to a low blood volume. The sudden, rapid loss of 30% of the total blood volume often results in death unless there is immediate medical care given.

In a slowly developing anemia cardiac output increases, blood is shunted from non vital organs and hemoglobin oxygen affinity decreases due to increased levels of 2-3-DPG and the Bohr effect.

Total blood volume remains remarkably constant. More than 50% of the red cell mass can be lost slowly with minimal effect. Anemia is a sign of disease, not the disease itself. The clinical effects include tiredness, lassitude, weakness, pallor and perhaps fever and low blood pressure. Shortness of breath and chest pain can occur after exercise. Yellow discoloration of the skin may occur in some anemias.

A pragmatic definition of anemia is a state which exists when the hemoglobin is less than 12 g/dL or the hematocrit is less than 37 cL/L.

Why is anemia dangerous to the diver?

It all comes down to the transport of oxygen by the red blood cell. Air is a mixture of gases, each of which contributes a share of the total atmospheric pressure called its partial pressure. Partial pressures are important because they determine the rate of diffusion of a gas, and therefore strongly affect the rate of gas exchange between the blood and alveolar air. The greater the partial pressure of oxygen in the alveolar air, the more oxygen dissolves in the blood (a restatement of Henry's Law). Partial pressures change as a diver descends and ascends in the water column.

At the alveolus, the blood is said to unload carbon dioxide and load oxygen. The efficiency of both processes depends on the length of stay of an erythrocyte in an alveolar capillary, and how long it takes for oxygen and carbon dioxide to reach equilibrium in the capillary blood.

Hemoglobin consists of four protein (globin) chains, each with one heme group. Each heme can bind 1 O₂ to the ferrous ion at its center: one hemoglobin molecule can carry up to 4 O₂. If only one oxygen is carried on the hemoglobin, it is still referred to as oxyhemoglobin (HbO₂). The poisonous effect of carbon monoxide stems from its competition for the same binding site as oxygen.

When oxyhemoglobin in the blood reaches an area in the tissues with a much lower partial pressure of oxygen (in metabolically active tissues), the

oxyhemoglobin unloads its oxygen, which then diffuses into the tissues. Hemoglobin unloads more oxygen into the tissues that need it most.

Are there any conditions of the blood that will disqualify a person from diving?

NOAA Scuba Hematologic Disqualifications Hematological

- Sickle cell anemia should be disqualifying.
 - Leukemia or pre-leukemia manifesting as myelofibrosis and polycythemia should be disqualifying.
 - Anemia is relatively disqualifying and requires case-by-case evaluation.
 - Intoxication that has caused methemoglobinemia should be disqualifying.
-

Oxygen Content Equation

All physicians know that hemoglobin carries oxygen and that anemia can lead to severe hypoxemia. However, the partial pressure of oxygen and the concentration (content) of O₂ requires knowledge of the oxygen content equation in order to be understood.

$$CaO_2 = (SaO_2 \times Hb \times 1.34) + .003(PaO_2)$$

Oxygen is a gas and its molecules do exert a pressure but, like any other substance, oxygen also has a finite content in the blood, in units of ml O₂/dl blood. Tissues have to have a certain amount of oxygen per minute in order to live, a need met by **oxygen content**, not oxygen pressure. (Patients can and do live with very low PaO₂ values, as long as their oxygen content and cardiac output are adequate.)

The oxygen carrying capacity of one gram of hemoglobin is 1.34 ml.

Given normal pulmonary gas exchange (i.e., a normal respiratory system), factors that lower oxygen content - such as anemia, carbon monoxide poisoning, methemoglobinemia, shifts of the oxygen dissociation curve - do not affect PaO₂. PaO₂ is a measurement of pressure exerted by uncombined oxygen molecules dissolved in plasma; **once oxygen molecules chemically bind to hemoglobin they no longer exert any pressure.**

PaO₂ affects oxygen content by determining, along with other factors such as pH and temperature, the **oxygen saturation of hemoglobin** (SaO₂).

When hemoglobin content is adequate, patients can have a reduced PaO₂ (defect in gas transfer) and still have sufficient oxygen content for the tissues (e.g., hemoglobin 15 grams%, PaO₂ 55 mm Hg, SaO₂ 88%, CaO₂ 17.8 ml O₂/dl blood). Conversely, patients can have a normal PaO₂ and be profoundly hypoxemic by virtue of a reduced CaO₂. This paradox - normal PaO₂ and hypoxemia - generally occurs one of two ways: 1) anemia, or 2) altered affinity of hemoglobin for binding oxygen.

A common misconception is that anemia affects PaO₂ and/or SaO₂; if the respiratory system is normal, anemia affects neither value.

Obviously, however, the lower the hemoglobin content the lower the oxygen content. It is not unusual to see priority placed on improving a chronically hypoxemic patient's low PaO₂ when a blood transfusion would be far more beneficial.

Anemia can also confound the clinical suspicion of hypoxemia since anemic patients do not generally manifest cyanosis even when PaO₂ is very low. Cyanosis requires a minimum quantity of de-oxygenated hemoglobin to be manifest - approximately 5 grams% in the capillaries. A patient whose hemoglobin content is 15 grams% would not generate this much reduced

hemoglobin in the capillaries until the SaO₂ reached 78% (PaO₂ 44 mm Hg); when hemoglobin is 9 grams% the threshold SaO₂ for cyanosis is lowered to 65% (PaO₂ 34 mm Hg).

Altered hemoglobin affinity may occur from shifts of the oxygen dissociation curve (e.g., acidosis, hyperthermia), from alteration of the oxidation state of iron in the hemoglobin (methemoglobinemia), or from carbon monoxide poisoning.

This page is written and maintained by [Ernest S Campbell, MD.](#)

It may be used freely with appropriate credit.

[Register & Questions](#) || [DiveMed Email Logon](#) || [FAQ](#) || [Message Board](#) || [Websearch](#) || [Medline](#) || [Music](#) || [Bookstore](#) ||
[Conferences](#) || [Email Us](#) || [Contact Us](#) || [Glossary](#) || [Medical Center](#) || [FreeStuff](#) || [Dictionary](#) || [View](#)[Guestbook](#)[Sign](#)
