Alveolar gas equation:

The alveolar gas equation estimates alveolar oxygen content given a few readily measurable variables. The pAO2 derived from performing the calculation can then be used to discern the degree of shunt present in a patient. Practical simplification of the complex formula allows for the following equation:

$$pAO2 = FiO2\ (Patm - pH20) - (paCO2/RER)$$

Where in the average person the respiratory exchange ratio (RER) (or respiratory quotient) is typically considered to be 0.8 (varies depending on the diet and primary source of fuel the patient is utilizing such as fat, protein or carbohydrates)

At sea level, the atmospheric pressure is 760 mmHg and the vapor pressure of water at body temperature is 47 mmHg. Plugging these rough numbers into the aforementioned equation leads to the following simplification at sea level:

$$pAO2 = (FiO2 \times 713\ mmHg) - (paCO2/0.8)$$

Given that increasing altitude decreases the atmospheric pressure, for any given FiO2 you would expect a lower pAO2 and, consequently, a lower paO2. For example, whereas breathing 100% oxygen at sea level would result in an alveolar pO2 of 663 mmHg, breathing 100% oxygen on Mt. Everest at a barometric pressure of 263 mmHg would result in a pAO2 of 166 mmHg (assuming the pH2O, paCO2 and RER to be the same). This results in hypoxia which triggers all manner of physiologic changes that can include but are not limited to: respiratory alkalosis (as seen in acute mountain sickness), mental status changes, increased heart rate and cardiac output, decreased systemic vascular resistance, pulmonary vasoconstriction/hypertension (as seen in chronic mountain sickness with potential evolution of cor pulmonale), and cerebral edema, among others.

Conversely, increasing the barometric pressure can have significant effects by increasing the amount of dissolved oxygen. It’s for this reason that hyperbaric oxygen therapy has been implemented for the treatment of non-healing wounds, decompression sickness, and carbon monoxide poisoning, among others.

Though not specific to altitude necessarily, the alveolar gas equation illustrates is that, by definition, hypoventilation (and increases in PaCO2) will result in a relative hypoxemia given all other variables in the equation are held steady. For any given patient, this fact may or may not have any clinical relevance.

The A-a gradient, or the alveolar-arterial gradient, measures the difference between the oxygen concentration in the alveoli and arterial system. The A-a gradient has important clinical utility as it can help narrow the differential diagnosis for hypoxemia. The A-a gradient calculation is as follows:

- A-a Gradient = PAO2 – PaO2.
- With PAO2 representing alveolar oxygen pressure and PaO2 representing arterial oxygen pressure.

So there exists a physiologic A-a gradient due to physiologic shunt and venous admixture which changes based on a patient's age. Expected A-a gradient can be estimated with the following equation:

- A-a gradient = (Age + 10) / 4

The value calculated for a patient's A-a gradient can assess if their hypoxia is due to the dysfunction of the alveolar-capillary unit, for which it will elevate, or due to another reason, in which the A-a gradient will be at or lower than the calculated value using the above equation.