

Chapter 2

Pulmonology: The Lungs, Oxygen, and Perfusion

Arteries in the pulmonary vasculature *constrict* if the air in the alveoli near them doesn't have the expected amount of oxygen (approximately 21 % or greater at sea level). Substances that make this response even more pronounced are:

Dopamine
Propranolol
Almitrine (a ventilatory stimulant)
Acidosis

Substances or situations that blunt this "hypoxic lung response" by the pulmonary arterial system include:

Beta agonists
Calcium channel blockers
Anesthetics
Prostaglandins
Vasodilators (in general)
High cardiac output (pushes more blood into the constricted areas)
Alkalosis

If one of these "blunting" circumstances is present, and your patient has a mismatch between the ventilation and perfusion of the lung, *the mismatch will actually worsen!* This makes sense because areas that are *not* well ventilated will be well perfused.

Remember that "V" stands for "ventilation" when oxygenation is being discussed, while "Q" stands for "perfusion." There must be a story as to how the letter "Q" was selected, but I haven't heard it.

Also remember that, throughout the normal lung, there are a variety of V:Q ratios. The top of the lung ordinarily receives more ventilation than it should for its amount of blood flow, because gravity has a big effect on the blood flow in the lung.

The bottom of the lung, on the other hand, is overperfused, and doesn't have great ventilation. Think of it as gravity making it hard to lift and open the bottom

part of the lung, so it's not very well ventilated, yet the blood likes to pool there, because it's at the bottom of the lung.

Blood samples that we obtain reflect the "average" of all of the V:Q relationships throughout the lung.

Neonates and Normal Oxygen Tension

Interestingly, normal neonates close off significant portions of their lung during ordinary exhalation (due to low chest wall compliance, mainly). This means that their PaO₂ (arterial partial pressure of oxygen) is normally significantly lower than you would expect in an adult or an older child.

The Alveolar Gas Equation and the A-a Gradient

The alveolar gas equation allows us to calculate how much oxygen is in the alveoli. We need to do this to anticipate how much oxygen should be circulating in the blood. The amount of the oxygen in the alveoli is expressed as the partial pressure of oxygen in the alveoli (in the equations, alveolar values have a capital "A").

The partial pressure of oxygen in the alveoli is always a little less than the partial pressure of oxygen in the air inspired. Why is that?

The partial pressure of oxygen must be *less* in the alveoli than in the air inspired because alveolar oxygen is mixed with both the carbon dioxide leaving the blood via the alveolar capillary and diffusing into the alveolus, and because there is always some water vapor doing the same thing. The alveolar gas equation therefore includes a factor for the partial pressure of the water vapor and a factor for the carbon dioxide the body is releasing into the alveolus. The alveolar partial pressure of oxygen usually works out to be 100, at sea level.

The Alveolar Gas Equation

$$PAO_2 = (\text{fraction } O_2 \text{ inspired})(\text{barometric } P - \text{water vapor } P) - PaCO_2 / 0.8$$

Room air inspired O₂ fraction=0.21 (this may be more if you are giving O₂).

Barometric pressure – water vapor pressure = 760 – 47 = 713.

The whole first term is usually, therefore, 713(0.21), which equals 150.

The arterial pressure of CO₂ is taken from the ABG measurement of CO₂. It is divided by 0.8 as a correction factor, because the body produces a little less CO₂ than it consumes O₂.

The whole equation equals about 100, if a healthy patient is breathing room air at about sea level.

The A–a Gradient

We expect the partial pressure of oxygen in the blood to be at a certain level for any given level of oxygen in the alveolar air. There are a few factors in the body's use of oxygen that make the two oxygen tensions slightly different, but they do have a predictable relationship:

$$PAO_2 - PaO_2 = A - a O_2 \text{ gradient}$$

In English, the alveolar partial pressure of oxygen – the arterial partial pressure of oxygen = the gradient, or the difference, between them. *The normal gradient in a healthy young adult is around 10, and in children it can be less than 10.*

Non-pulmonary reasons that the A–a gap can widen, or increase, include advancing age (the elderly), obesity, fasting, lying supine for an extended period, and vigorous exercise.

Hypoxemia

How does it happen?

1. Alveolar hypoventilation – If the patient doesn't breathe in enough oxygen, the patient becomes hypoxic/hypoxemic (for example, due to CNS depression or muscular weakness).
2. Diffusion impairment – If the patient breathes in enough oxygen, but the oxygen can't easily cross the alveolar membrane (due to thickening, or due to something coating or covering the membrane), then the patient may become hypoxemic.
3. Intrapulmonary shunting – If too much blood is shunted to the left side of the heart without being properly ventilated in the alveoli, then the patient may become hypoxic. This can occur due to structural problems in the vasculature and also due to areas of collapsed or fluid-filled alveoli.
4. V:Q mismatch – If too much blood is sent to poorly ventilated areas of the lung (such as the bottom of the lung or an area with a blocked bronchus), V:Q mismatch will occur. If the mismatch is significant enough, the patient will become hypoxic.

Similarly, if areas of lung are being ventilated, but not very well perfused, as is the case with a pulmonary embolus, then the patient may become hypoxic.



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