**DEFINITIONS**

**Hypoxia** – insufficient oxygen delivered to tissues to meet demands

**Hypoxemia** – low oxygen in the blood (most common type of hypoxia)

- \( P_{O_2} \) – atmospheric oxygen (how much \( O_2 \) is inspired)
- \( P_{O_2} - \) alveolar oxygen (how much \( O_2 \) reaches the alveoli)
- \( P_{O_2} \) – oxygen dissolved in arterial blood (measured on ABG)

- \( \text{SaO}_2 \) – percent saturation of hemoglobin in arterial blood
- \( \text{CaO}_2 \) – oxygen content of art. blood (dissolved \& Hb bound)

**HYPOXEMIC HYPOXIA**

Insufficient oxygen in the blood (the most common type of hypoxia)

- Low \( \text{PaO}_2 \)

**ISCHEMIC HYPOXIA**

Insufficient blood flow to tissues, also called **stagnant hypoxia**

(e.g. low cardiac output)

- Low \( \text{SVo}_2 \) \( \rightarrow \) Low \( \text{PaO}_2 \)

**ANEMIC HYPOXIA**

Insufficient \( O_2 \) carrying capacity

(e.g. severe blood loss) or abnormal hemoglobin (e.g. COHb, MetHb)

- Low \( \text{CaO}_2 \) \( \rightarrow \) Low \( \text{SVo}_2 \) \( \rightarrow \) Low \( \text{PaO}_2 \)

**CYTOPATHIC HYPOXIA**

Cells cannot use oxygen

(e.g. cyanide toxicity, *maybe sepsis*)

- High \( \text{PaO}_2 \), High \( \text{SVo}_2 \)

**LOW INSPIRED OXYGEN (P\(_{O_2}\))**

Fewer \( O_2 \) molecules enter the lungs with respiration (low \( \text{PaO}_2 \))

- Normal \( Aa \) difference

- \( \text{PaO}_2 \) normalizes with supplemental oxygen

- Causes: *low atmospheric pressure* (e.g. high altitude), or *low partial pressure of oxygen* (\( \text{FiO}_2 < 0.21 \) e.g. confined space, low \( O_2 \) gas mixtures)

**LOW MIXED VENOUS O\(_2\) (S\(_{vO_2}\))**

Venous blood returning to the lungs (\( \text{SvO}_2 \)) has very low \( O_2 \) due to increased extraction.

- Normal \( Aa \) difference

- \( \text{PaO}_2 \) normalizes with supplemental oxygen

- Causes: severe anemia (low \( \text{CaO}_2 \) rarely a problem unless \( \text{Hb} < 5 \)), low cardiac output, \& extremely high oxygen consumption

**ALVEOLAR HYPOVENTILATION**

Fewer \( O_2 \) molecules reach the alveoli due to decreased ventilation (low \( \text{P}_{O_2} \)).

- Normal \( Aa \) difference

- \( \text{PaO}_2 \) normalizes with suppm. \( O_2 \)

- Increased \( \text{P}_{O_2} \)

- Causes: decreased respiratory drive (opioids, brainstem stroke, OHVS), *neuromuscular weakness* (GBS, ALS), chest wall problems (kyphoscoliosis, flail chest) or *airflow obstruction* (COPD, asthma)

**V/Q MISMATCH**

Imbalance between regional lung ventilation and perfusion (low V/Q).

- Most common cause of hypoxemia

- Increased \( Aa \) difference

- \( \text{PaO}_2 \) normalizes with suppl. \( O_2 \)

- Causes: *obstructive lung diseases* (COPD), *pulmonary vascular disease* (PE), *alveolar filling processes* (pneumonia, pulmonary edema), *interstitial disease \& atelectasis*

**SHUNT**

Blood passes from the right side of the heart to the left side without being oxygenated.

- Increased \( Aa \) difference

- \( \text{PaO}_2 \) does NOT normalize with supplemental oxygen

- Causes: *anatomical* (ASD, VSD, pulm AVMs) \& *physiological shunts* (atelectasis, pneumonia, ARDS) where blood bypasses alveoli without effective gas exchange

**DIFFUSION LIMITATION**

Impaired \( O_2 \) diffusion from alveoli to RBC, causing hypoxemia particularly in with increased cardiac output.

- Increased \( Aa \) difference

- \( \text{PaO}_2 \) normalizes with suppm. \( O_2 \)

- Causes: pulmonary fibrosis, edema, & inflammation that impair gas exchange in the alveoli

**OXYGEN DELIVERY:**

Tissue hypoxia occurs when DELIVERY of OXYGEN (DO\(_2\)) is inadequate to meet metabolic demands. DO\(_2\) depends on CARDIAC OUTPUT (CO) \& the OXYGEN CONTENT OF BLOOD (Ca\(_{O_2}\))

\[
DO_2 = (HR \times SV) \times [(1.34 \times Hb \times \text{SaO}_2) + (\text{PaO}_2 \times 0.003)]
\]

\( O_2 \) bound to hemoglobin

\( O_2 \) dissolved in blood

\( \text{CaO}_2 \) = oxygen dissolved in arterial blood (measured on ABG)

\( \text{SvO}_2 \) = oxygen content of VO2

\( \text{CaO}_2 \) – oxygen content of arterial blood

Aa \( \Delta \text{O}_2 \) tension

\( \text{CaO}_2 \) – oxygen content of arterial blood

\( \text{SvO}_2 \) – oxygen content of venous blood

\( \text{P}_{aO_2} \) – alveolar oxygen (how much \( O_2 \) reaches the alveoli)

\( \text{P}_{O_2} \) – oxygen dissolved in arterial blood (measured on ABG)

\( \text{SaO}_2 \) – percent saturation of hemoglobin in arterial blood

\( \text{PaO}_2 \) – oxygen content of arterial blood

\( \text{FiO}_2 \) – fraction of inspired \( O_2 \)

\( \text{Hb} \) – hemoglobin

\( \text{Q} \) – respiratory quotient

\( \text{FiCO}_2 \) – fraction of inspired \( CO_2 \)

(760 mmHg @ sea level, 630 mmHg @ 1500m, 530 mmHg @ 3000m)

**HYPOXIA & HYPOXEMIA** by Nick Mark MD

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