



MED437  
KING SAUD UNIVERSITY



# Hypoxia & Cyanosis

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➤ Color index:

Red: important

Green: doctor's notes

Grey: extra information

Pink: found only in  
female's slides

Blue: found only in  
male's slides

Yellow: numbers

# objectives:

## By the end of the lecture you will be able to:

- By the end of this lecture you should be able to:
- Define hypoxia and list its various physiological and pathological causes.
- Define hypo and hyper-ventilation in terms of arterial PCO<sub>2</sub> and PO<sub>2</sub>.
- Define cyanosis and its clinical presentation
- Define ventilation/perfusion ( $\dot{V}/\dot{Q}$ ) ratio and its normal values.

الدكتور سلطان ما وضعها في سلايداته وقت المحاضرة لكن  
سلايدات المراجعة وضعها ونبه على أهميتها

# Hypoxia

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Hypoxia vs hypoxemia:  
Hypoxia is the deficiency of O<sub>2</sub> in tissue  
Hypoxemia is the deficiency of O<sub>2</sub> in blood

**Hypoxia** is defined as an **inadequate supply of oxygen** to the body tissues.  
(deficiency of oxygen in the tissue cells)

It can be classified in the following types:

1. Hypoxic hypoxia (arterial hypoxia) e.g. at high altitudes, low O<sub>2</sub> in air
2. Anemic hypoxia decreased percentage of hemoglobin in blood with respect to age & gender, could be caused by severe loss of blood
3. Stagnant hypoxia (Hypokinetic or Ischemic hypoxia) lack of blood supply
4. Histotoxic hypoxia tissues are unable to utilize O<sub>2</sub>

# CLASSIFICATION BASED ON THE CAUSES OF HYPOXIA

1. **Inadequate oxygenation of the blood** in the lungs because of **extrinsic reasons**
  - a. Deficiency of oxygen in the atmosphere
  - b. Hypoventilation (neuromuscular disorders)
2. **Pulmonary disease**
  - a. Hypoventilation caused by increased airway resistance or decreased pulmonary compliance
  - b. Abnormal alveolar ventilation-perfusion ratio (including either increased physiologic dead space or increased physiologic shunt) from alveolar damage
  - c. Diminished respiratory membrane diffusion **due to increased thickness of membrane e.g. emphysema**
3. **Venous-to-arterial shunts** ("right-to-left" cardiac shunts). **Damage of septum between atria or ventricles → deoxygenated blood in systemic circulation → hypoxia**

# Cont.

4. **Inadequate oxygen transport to the tissues** by the blood
  - a. Anemia or abnormal hemoglobin
  - b. General circulatory deficiency
  - c. Localized circulatory deficiency (peripheral, cerebral, coronary vessels)
  - d. Tissue edema e.g. pleural edema impairs diffusion of gases → hypoxia
  
5. **Inadequate tissue capability of using oxygen** tissue receives O<sub>2</sub> but can't use it
  - a. Poisoning of cellular oxidation enzymes this is how cyanide works
  - b. Diminished cellular metabolic capacity for using oxygen, because of toxicity, vitamin deficiency, or other factors.

# Hypoxic Hypoxia

باختصار هي أن الأكسجين ما يقدر يكون بتركيز  
كافي في الدم مع أن الدم سليم

Hypoxic hypoxia is also known as **arterial hypoxia**. This is seen when there is a lack of oxygenation of blood in the lungs, which leads to a low  $PO_2$  in arterial blood. Since less amounts of Hb is converted to oxy-Hb. The tissues are supplied with blood deficient (نقص) in oxygen. Hypoxic hypoxia can occur in the following conditions:

- High altitude (leading cause)
- Fluid in the lungs (pulmonary edema)
- Obstruction in the respiratory passages e.g. obstruction of bronchi
- Emphysema

# Hypoxic Hypoxia

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## Other causes of hypoxic hypoxia:

- Alveolar hypoventilation
- Diffusion abnormalities. E.g pulmonary edema & pneumonia
- Right to left shunt
- Ventilation-perfusion imbalance (including increased physiological dead space and physiological shunt → similar to Venous-to-arterial shunt. Only treatment is through surgery of septum).

## Alveolar hypoventilation:

e.g.

- Reduced PO<sub>2</sub> in inspired air (high altitude).
- Increased airway resistance.
- Reduced lung compliance. Compliance is the ease at which the lung can expand
- Paralysis of respiratory muscles
- Depressed respiratory centre.

Only in male's slides.

# Hypoxic Hypoxia

## **Diffusion abnormalities:**

Impaired diffusion from alveolar to pulmonary capillary blood can lead to arterial hypoxia. It is seen in conditions like alveolar-capillary block.

## **Ventilation-perfusion imbalance (including increased physiological dead space and physiological shunt):**

If ventilation and blood flow are mismatched in various parts of the lung, impairment of both oxygen and carbon dioxide diffusion results.

Ventilation perfusion imbalance may be caused by uneven ventilation, (e.g. obstructive lung conditions) , or uneven perfusion, (e.g. consolidation of the lung).

## **Right to left shunt:**

Blood passes from the systemic venous without going through the gas exchanging part of the lungs. This type of hypoxia can be differentiated clinically from other types by giving the subject 100% oxygen to breathe. Hypoxia because of the shunt will not be abolished while in other types PO<sub>2</sub> in the arterial system will improve considerably. **It's congenital disorder.**



# Anemic Hypoxia

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This condition is characterized by **decreased oxygen carrying capacity** of the blood due to decreased hemoglobin level **or abnormal type of hemoglobin which is unable to carry oxygen.**

## Causes:

- Anemia.
- Abnormal Hb (**Altered haemoglobin formation**) e.g. methaemoglobin, sulfhemoglobin, and carboxyhemoglobin. **High concentrations of abnormal Hb impair the blood's capacity to carry oxygen**
- **Hemorrhagic anemia [Decreased RBC / quality].**Quantity could be decreased from trauma or any other loss of blood. While quality could be caused by improper formation of RBCs.\*
- **The failure of hemoglobin to carry its normal concentration of oxygen, as in carbon monoxide (CO) poisoning.**

\*Presence of the Nucleus in RBCs is a clear indicator of improper formation

# Stagnant Hypoxia

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**Stagnant hypoxia** (Hypokinetic or Ischemic hypoxia) occurs in conditions in which there is a **decreased rate of blood flow** throughout the body or a part of the body (tissue). so more and more oxygen is extracted from the blood, and due to slow circulation less oxygen is carried by the blood at the lung , leading to hypoxia.

## Causes:

- It may be caused by **congestive heart failure**, **circulatory shock** and **arteriosclerosis\***.
- General slowing of circulation (heart failure and shock).
- Local slowing: vasoconstriction, cold and arterial wall spasm.

**Arteriosclerosis: decrease of the diameter of a blood vessel due to fat deposition**

.stagnant hypoxia in the hand الدكتور شبيهها بمثل لما تضغط بشدة على مفصل اليد وتحبس الدم عنها فصار

# Histotoxic Hypoxia

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In **histotoxic hypoxia** the **tissues are unable to use oxygen** even though plenty of oxygen is available.

**Caused by:** inhibition of the tissue respiration electron transport chain (inhibition of the oxidative enzyme activity)

**The best example:** **cyanide poisoning**, where tissue cytochrome oxidases are knocked out and tissue is unable to utilize oxygen.

# Hypoxia & Clinical features

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**Signs and symptoms of hypoxia** : clinical features depend on how fast and how severely partial pressure of O<sub>2</sub> is decreased.

## Fulminant hypoxia

This occurs very rapidly, within seconds. Unconsciousness occurs in 15-20 seconds and brain tissue death occurs in 4-5 minutes.

## Acute hypoxia

In acute hypoxia body reflexes are slowed, there may be slurred speech, unconsciousness, coma and death may occur.

## Chronic hypoxia

The symptoms of chronic hypoxia, fatigue, difficulty in breathing, and shortness of breath can occur.

**Signs of hypoxia** : Cyanosis, Tachycardia and Tachypnea (breathing rapidly).

# Effects of hypoxia on the body

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Hypoxia, if severe enough, can cause death of cells throughout the body, but in less severe degrees it causes principally depressed mental activity, sometimes culminating in coma, reduced work capacity of the muscles.

At 12,000 feet, **drowsiness, lassitude, mental and muscle fatigue, sometimes headache, occasionally nausea, and euphoria**. These effects progress to a stage of twitchings or seizures above 18,000 feet and above 23,000 feet in the unacclimatized person, in coma, followed shortly thereafter by death.

One of the most important effects of hypoxia is **decreased mental proficiency, which decreased judgment, memory, inability to perform complex calculations and performance of discrete motor movements**. If an unacclimatized aviator stays at 15,000 feet for 1 hour, mental proficiency ordinarily falls to about 50% of normal, and after 18 hours at this level it falls to about 20% of normal.

## Treatment of hypoxia

- Administration route: Is giving by oxygen therapy in a tent or high oxygen tension mask.

This is useful in **hypoxic hypoxia**, but of less value in other types of hypoxia. Histotoxic hypoxia will not benefit from O<sub>2</sub> therapy



## Hypercapnia

Excess of CO<sub>2</sub> in body fluid, it usually occurs with hypoxia, PCO<sub>2</sub> increases above 52 mmHg, it decreases the PH.

- Features of hypercapnia :
  1. Peripheral vasodilation
  2. Sweating
  3. Warm extremities and bounding pulse
  4. Muscle twitching
  5. headache, drowsiness and coma
  6. Papilledema ( swelling of optic disc)

# Cyanosis

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The term cyanosis means **blueness of the skin and mucous membrane**, and is caused by excessive amounts of deoxygenated hemoglobin in the skin blood vessels, especially in the capillaries.

This deoxygenated hemoglobin has an intense dark blue-purple color that is transmitted through the skin.

Cyanosis appears whenever **the arterial blood contains more than 5 grams of deoxygenated hemoglobin in each 100 millimeters of blood**.

# CYANOSIS

A person with *anemia almost never becomes cyanotic* because there is not enough hemoglobin for 5 grams to be deoxygenated in 100 milliliters of arterial blood. (Anemia > Less blood cells > Less hemoglobin to be deoxygenated > Cyanosis cannot be achieved due to the lack of hemoglobin and red blood cells).

Conversely, in a person with excess red blood cells, as occurs in *polycythemia vera*, the great excess of available hemoglobin that can become deoxygenated leads frequently to cyanosis, even under otherwise normal conditions.

(Polycythemia > More blood cells > More hemoglobin to be deoxygenated > Cyanosis can be achieved due to the excess hemoglobin and red blood cells.)





# Causes of Cyanosis

## Inadequate oxygenation of blood in the lungs

- **High altitude**
- **Obstruction of respiratory passages**
- **Pneumoconiosis** (a disease of the lungs due to inhalation of dust, characterized by inflammation, coughing, and fibrosis)
- **Emphysema**
- **CO-poisoning**

## Presence of an aerated shunt between vessels

- **Coarctation of aorta**
- **Fallot's tetralogy**

## Other Causes

- **Moderate cold**
- **Diminished blood flow to tissues**

# Types of cyanosis

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graph TD; A[Types of cyanosis] --> B[Local cyanosis]; A --> C[Generalized cyanosis];
```

## **Local cyanosis:**

This is seen during decreased blood flow through a part of the body as in Raynaud's disease. In this disease, circulation through the upper limb is impaired, it causes local cyanosis.

## **Generalized cyanosis:**

Generalized impairment of circulation as in the case of heart failure leads to generalized cyanosis. It also occurs in hypoxic hypoxia.

# CYANOSIS

Dr. Sultan says it's not very important

## **Causes of central cyanosis:**

- Cyanotic congenital heart-disease
- Fallot tetralogy
- Tricuspid atresia
- Ebstein's anomaly
- Pulmonary arteriovenous fistula
- Pulmonary diseases
- Acute pulmonary embolism
- Pneumonia
- Atelectasis
- Chronic Obstructive airway disease
- Restrictive lung disease
- Hemoglobin abnormalities

## **Causes of peripheral cyanosis**

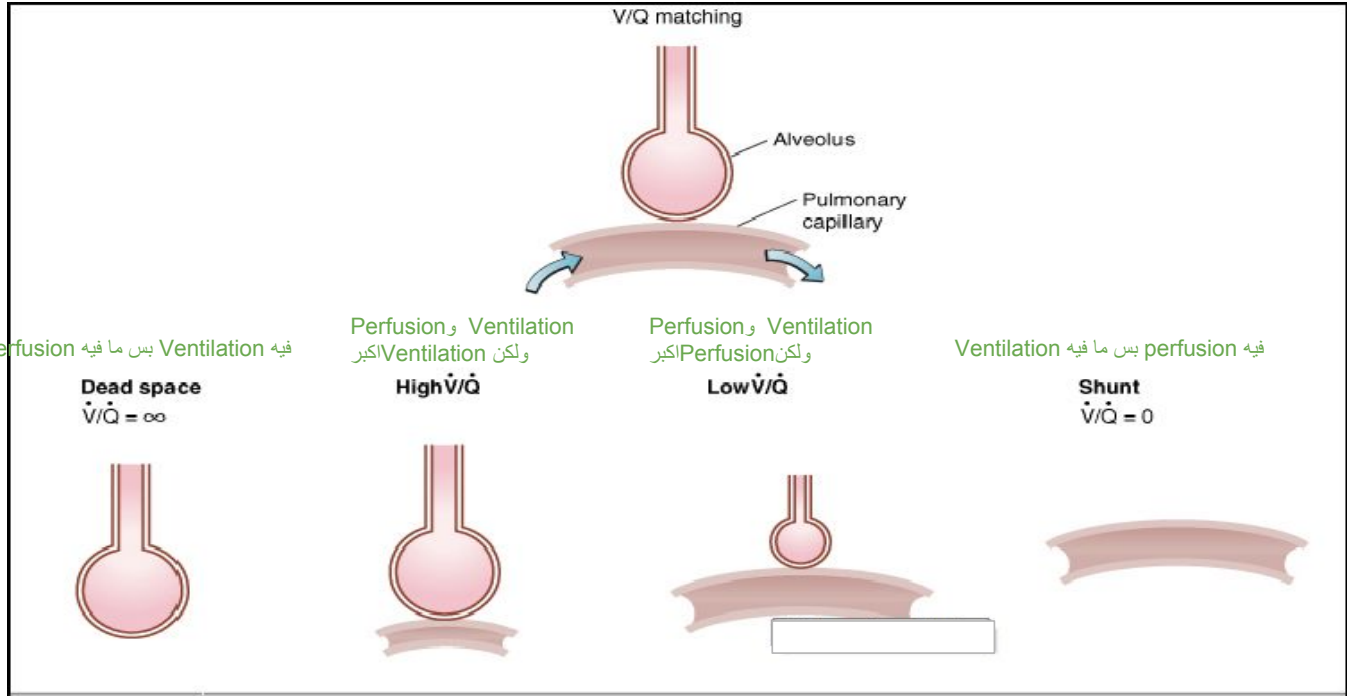
- Reduced cardiac output, as in congestive heart failure, mitral stenosis
- Exposure to cold
- Arterial obstruction
- Venous obstruction
- Raynauds disease
- Polycythemia vera

# Ventilation-perfusion ratio (V/Q)



- It is the ratio of alveolar ventilation to pulmonary blood flow per minute.
- The alveolar ventilation at rest (4.2 L/min)
- The pulmonary blood flow is equal to right ventricular output per minute (5L/min)
  - **SO, V/Q ratio =  $4.2 \div 5 = 0.84$**
- Average V/Q ratio across the lung is 0.8
- At the apex V/Q ratio = 3 **أكبر** فلما اقسام كبير على صغير تطلع النسبة كبيرة
- At the base V/Q ratio=0.6 **صغيرة** فلما اقسام على مقام كبير تطلع النسبة صغيرة
- So the apex is more ventilated than perfused and the base is more perfused than ventilated.
- During exercise the V/Q ratio becomes more homogenous among different parts of the lung.

# Ventilation/perfusion abnormalities



فيہ Ventilation بس ما فيہ Perfusion

Perfusion و Ventilation  
ولكن Ventilation اكبر

Perfusion و Ventilation  
ولكن Perfusion اكبر

فيہ perfusion بس ما فيہ Ventilation

**Dead space**  
 $\dot{V}/\dot{Q} = \infty$

**High  $\dot{V}/\dot{Q}$**

**Low  $\dot{V}/\dot{Q}$**

**Shunt**  
 $\dot{V}/\dot{Q} = 0$

ليه صار  
انفينتي؟ لأن  
قسمنا على  
Q=0 والي  
يهما هو أن  
فيه قاز  
اكستشينج

# Ventilation-perfusion ratio (V/Q)

ONLY IN FEMALES' SLIDES

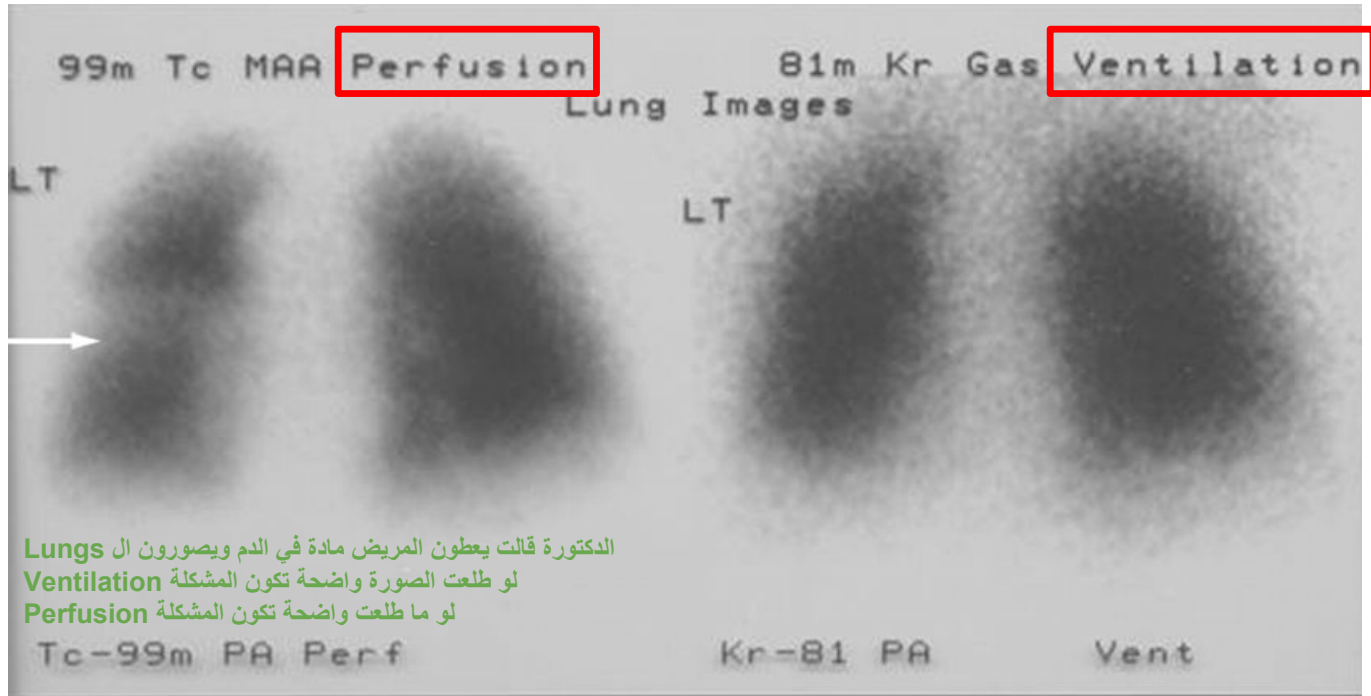
يشبه الي قبله لكن  
أوضح شوي  
3:34



- The main function of this ratio is to determine the state of oxygenation in the body.
- Any mismatch in the ratio can result in hypoxia.
- When the V/Q ratio is less than normal this is called **physiologic shunt** (a certain fraction of the venous blood is passing through the pulmonary capillaries **without being oxygenated** i.e shunted blood).
- When V/Q is more than normal this is called **Physiologic dead space** (when the ventilation of some of the alveoli is great but the alveolar blood flow is low, ventilation of these alveoli is wasted).

عكس بعض وحده  
النقص في الهواء  
الي يدخل والثانية  
نقص في البلور فلم

# Ventilation- Perfusion Lung Scan



الدكتورة قالت يعطون المريض مادة في الدم ويصورون ال  
Lungs  
لو طلعت الصورة واضحة تكون المشكلة  
Perfusion لو ما طلعت واضحة تكون المشكلة

# Abnormalities of the V/Q ratio

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ONLY IN FEMALES' SLIDES

- In the Upper and Lower regions of the normal lung
  - **Apex V/Q ratio = 3** (moderate degree of **physiologic dead space**)
  - **Base V/Q ratio = 0.6** (represent a **physiologic shunt**).
- **In Chronic Obstructive Lung disease COPD** because of bronchial obstruction in some areas and destruction of the alveolar septa in other areas with patent alveoli those people has some areas of the lung exhibit serious physiologic shunt and in other areas serious physiologic dead space.
- **COPD** is the most prevalent cause of pulmonary disability today, lung effectiveness as a gas exchange organ may decrease to **10%**



# SUMMARY

**Hypoxia** is defined as an inadequate supply of oxygen to the body tissues.

## **Hypoxic Hypoxia :**

This is seen when there is a lack of oxygenation of blood in the lungs, which leads to a low PO<sub>2</sub> in arterial blood.

## **Hypoxia** types :

- 1-Hypoxic hypoxia
- 2-Anemic hypoxia
- 3-Stagnant hypoxia
- 4-Histotoxic hypoxia

## Classification Based On The Causes Of Hypoxia :

- 1-Inadequate oxygenation of the blood.
- 2-Pulmonary disease.
- 3-Venous-to-arterial shunts.
- 4-Inadequate oxygen transport to the tissues.
- 5-Inadequate tissue capability of using oxygen.

## Anemic Hypoxia :

This condition is characterized by decreased oxygen carrying capacity of the blood due to decreased hemoglobin level or abnormal type of hemoglobin which is unable to carry oxygen.

# SUMMARY

**Stagnant Hypoxia :**  
occurs in conditions in which there is a decreased rate of blood flow throughout the body or a part of the body (tissue).

**Clinical features :**  
1-Fulminant hypoxia  
2-Acute hypoxia  
3-Chronic hypoxia

**Signs of hypoxia :**  
1-Cyanosis  
2-Tachycardia  
3-Tachypnea

**Histotoxic Hypoxia :**  
In **histotoxic hypoxia** the tissues are unable to use oxygen even though plenty of oxygen is available.

## **Cyanosis**

The term cyanosis means blueness of the skin and cause is excessive amounts of deoxygenated hemoglobin in the skin blood vessels, especially in the capillaries.

### **Causes of Cyanosis**

- 1-inadequate oxygenation of blood in the lungs
- 2-Presence of an aerated shunt between vessels
- 3-Other Causes

### **Types of cyanosis**

- 1-Local cyanosis
- 2-Generalized cyanosis

## Female's team:

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