CAUSES OF HYPOXEMIA

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OBJECTIVES

1. Define and distinguish between hypoxia, hypoxemia, anoxia and asphyxia.

2. Be able to calculate the A-a gradient, define its normal range, and describe its significance in distinguishing between the common causes of hypoxia.

3. Describe the clinically important causes of arterial hypoxemia.

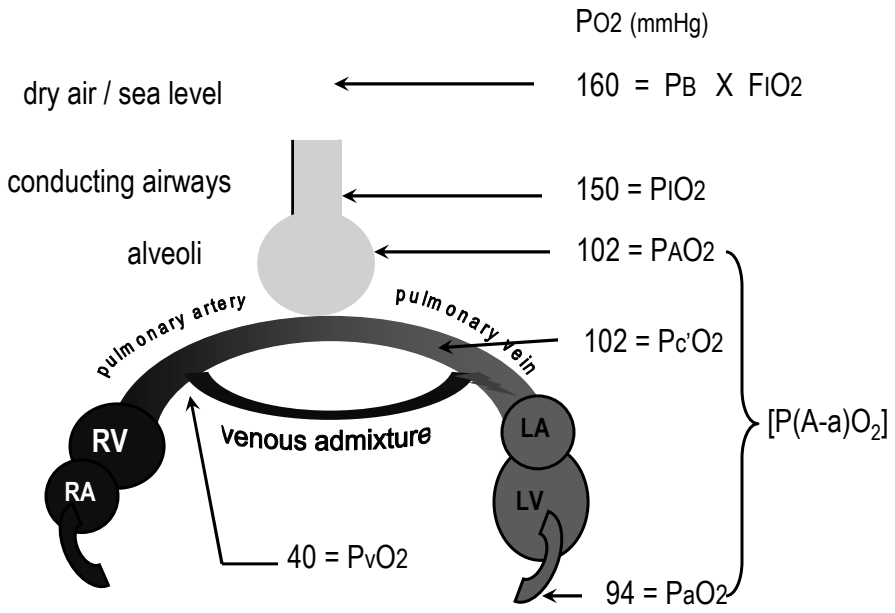
IMPORTANT TERMINOLOGY

Anoxia: absence of O_2 supply in the presence of perfusion- no oxygen

Asphyxia: absence of O_2 & accumulation of CO_2
example Kursk submarine

Hypoxia: ↓ O_2 in the body, often specified where in the body for
example: tissue hypoxia, alveolar hypoxia

Hypoxemia: ↓ O_2 in the blood. Specifically, hypoxemia is determined by measuring the PO_2 of arterial blood (plasma)



[P(A-a)O_2]

- normal range based on breathing room air (F_IO_2=0.21)
- normal range ↑ with aging due to↓ PaO_2 from ↑$\dot{V}/\dot{Q}$ mismatch
- due to venous admixture: anatomic shunt + $\dot{V}/\dot{Q}$ mismatch in healthy lungs
- due to venous admixture: anatomic shunt + ↑ $\dot{V}/\dot{Q}$ mismatch + physiologic shunt

CAUSES OF HYPOXEMIA

1. Hypoventilation
2. Low inspired oxygen
3. R-L shunt
4. $\dot{V}/\dot{Q}$ inequality (a.k.a. $\dot{V}/\dot{Q}$ mismatch)
5. Diffusion Impairment

• subdivided into those where there is an↑ in P(A-a)O_2 *versus* those where the A-a gradient remains within the normal range.

1. HYPOVENTILATION

- $P(A\text{-}a)O_2$ within normal range

↑ $PaCO_2$ (hypercapnia) ***** key feature**

What do you expect PAO2 to be high or low?
What do you expect PAO2 to be high or low?

How would you fix these problems?
↑ FIO_2 (supplemental oxygen) alleviates the hypoxemia
mechanical ventilation is required to eliminate hypercapnia

CAUSES OF HYPOVENTILATION

1. **CNS depression reducing respiratory motor output from the medulla**
   narcotics/sedatives, hypothyroidism, chemoreceptor insensitivity
2. **Inflammation, trauma or hemorrhage in the brainstem**
3. **Spinal cord disease: poliomyelitis**
4. **Diseases of the peripheral motor nerves: ALS, Guillain-Barré syndrome**
5. **Diseases of the neuromuscular junction: myasthenia gravis**
6. **Diseases of the respiratory muscles**
   muscular dystrophies, hypokalemaia, hypophosphatemia
7. **Chest wall abnormalities: kyphoscoliosis, flail chest, morbid obesity**
8. **Pleural space disorders: pleural fibrosis, pleural effusion, pneumothorax**
9. **Pulmonary parenchymal diseases: pulmonary fibrosis**
10. **Airway diseases: asthma/COPD, obstructive sleep apnea, tumors of trachea/larynx**

2. LOW INSPIRED OXYGEN (↓PIO2)

recall PIO2 = (PB - 47 mmHg) FIO2

- P(A-a)O2 within normal range
- PaCO2 normal or ↓ if hyperventilating

- What do you expect PAO2 to be high or low?
- What do you expect PAO2 to be high or low?

3. RIGHT TO LEFT SHUNT

- ↑ $P(A\text{-}a)O_2$
- $PaCO_2$ normal or low if hyperventilating

ANATOMIC SHUNT

A portion of blood bypasses the lungs through an anatomic channel

In all healthy individuals:

- **a portion of the bronchial circulation's venous blood drains into the pulmonary vein.**
- **a portion of the coronary circulation's venous blood drains through the thebesian veins into the left ventricle.**

ANATOMIC SHUNT

a portion of blood bypasses the lungs through an anatomic channel

In Disease States (Congenital abnormalities)

- **Intra-cardiac shunts**
- **Intra-pulmonary fistulas**

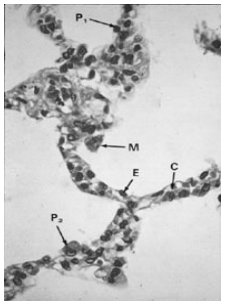
Tetrology of Fallot

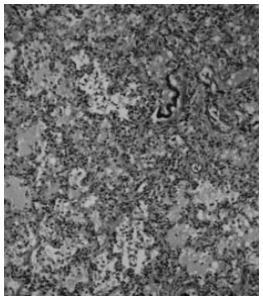
1. **Ventricular Septal Defect**
2. **Pulmonary Stenosis**
3. **Hypertrophy of R ventricle**
4. **Overriding aorta**

PHYSIOLOGIC SHUNT

a portion of cardiac output that goes through the normal pulmonary vasculature but does not come into contact with alveolar air due to filling of the alveolar spaces with fluid

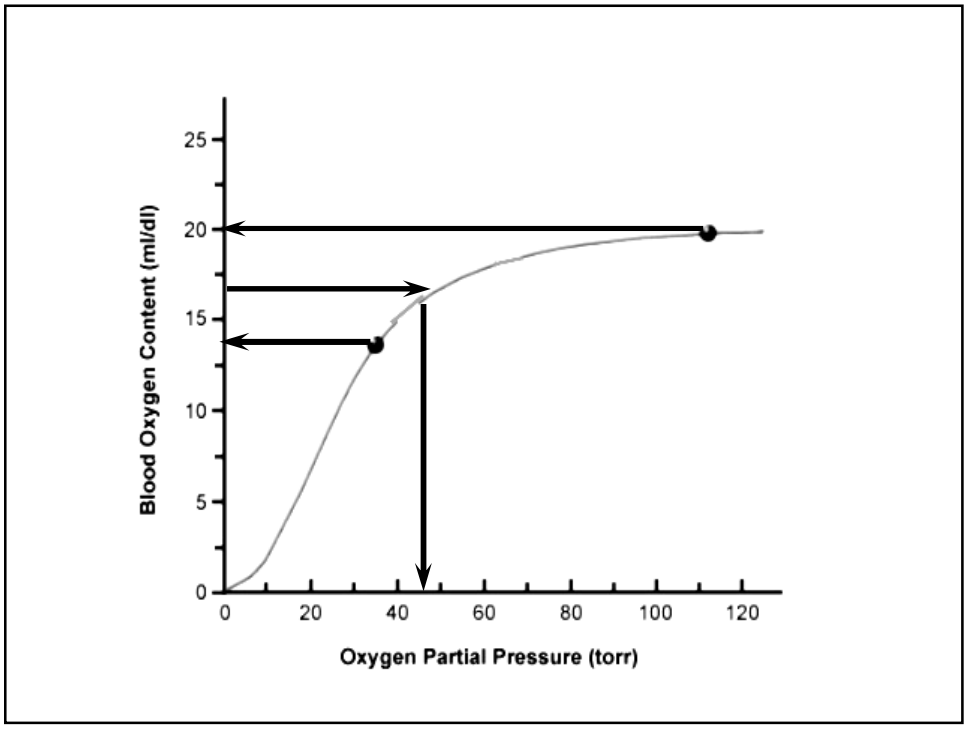
Examples:
- **drowning**
- **pulmonary edema**

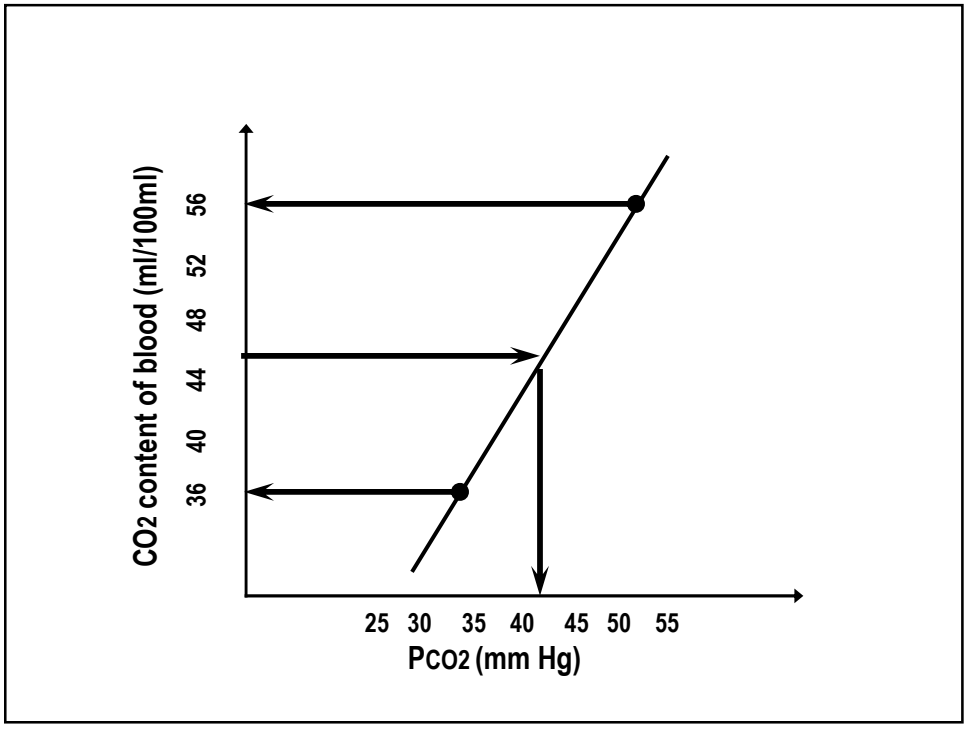




KEY CLINICAL FEATURE OF R-L SHUNTS

The accompanying hypoxemia
can not be corrected
with supplemental oxygen


Blood Oxygen Content (ml/dl)
25
20
15
10
5
0
0
20
40
60
80
100
120
Oxygen Partial Pressure (torr)

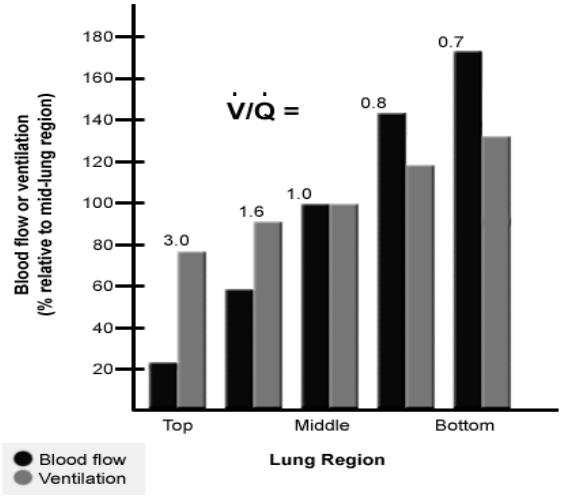

CO2 content of blood (ml/100ml)
56
52
48
44
40
36
25
30
35
40
45
50
55
PCO2 (mm Hg)

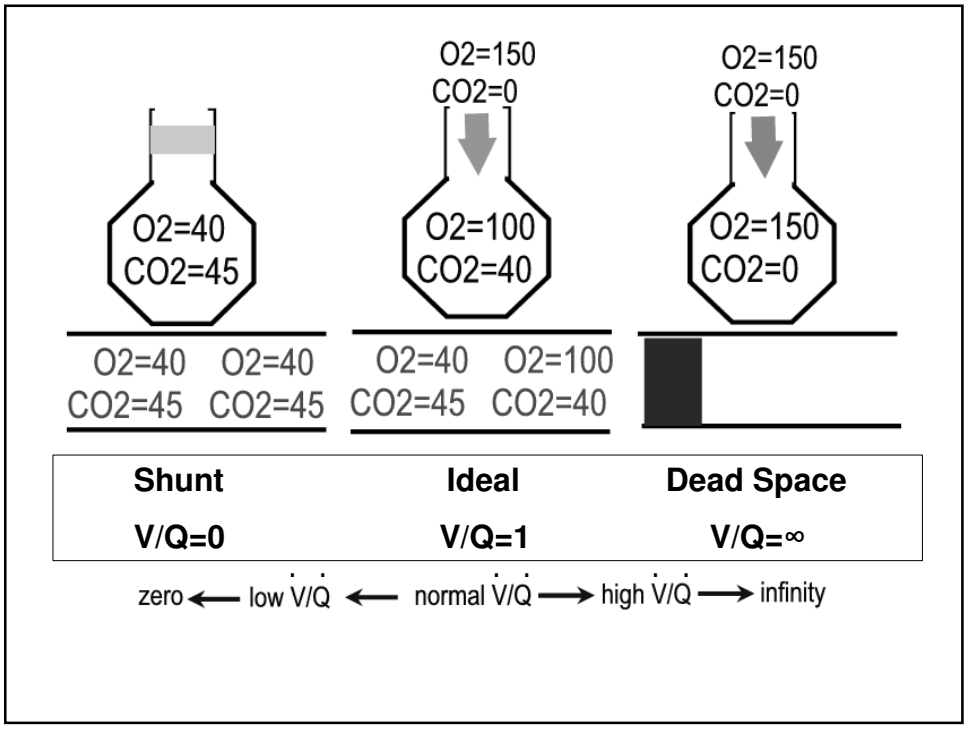
4. VENTILATION PERFUSION INEQUALITY

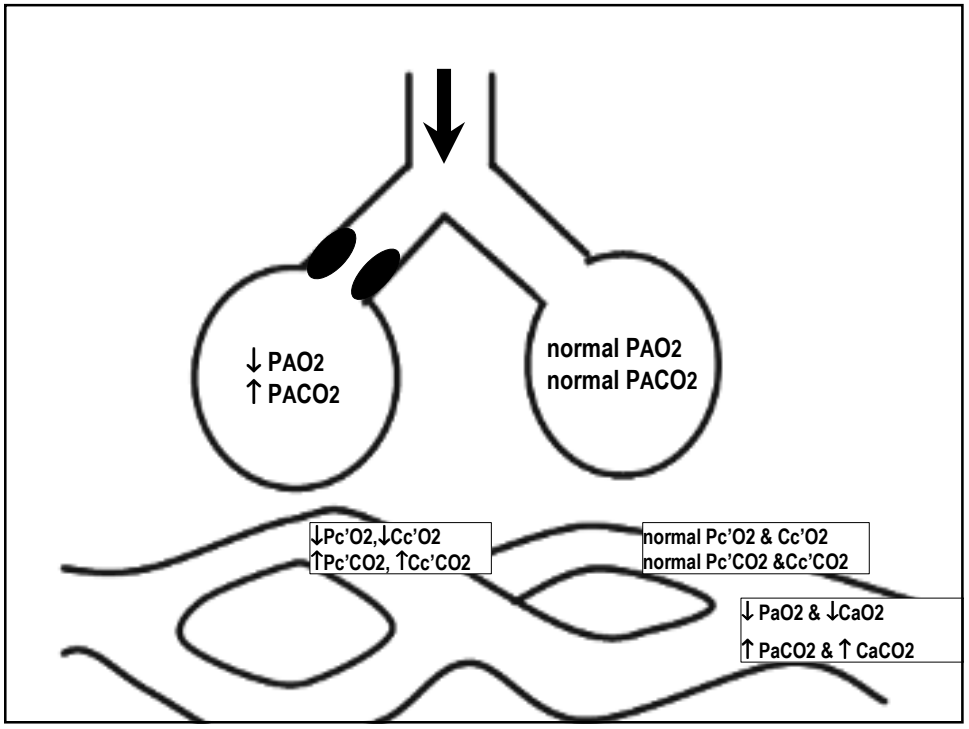
- ↑ $P(A\text{-}a)O_2$
- $PaCO_2$ within the normal range or decreased if hyperventilating

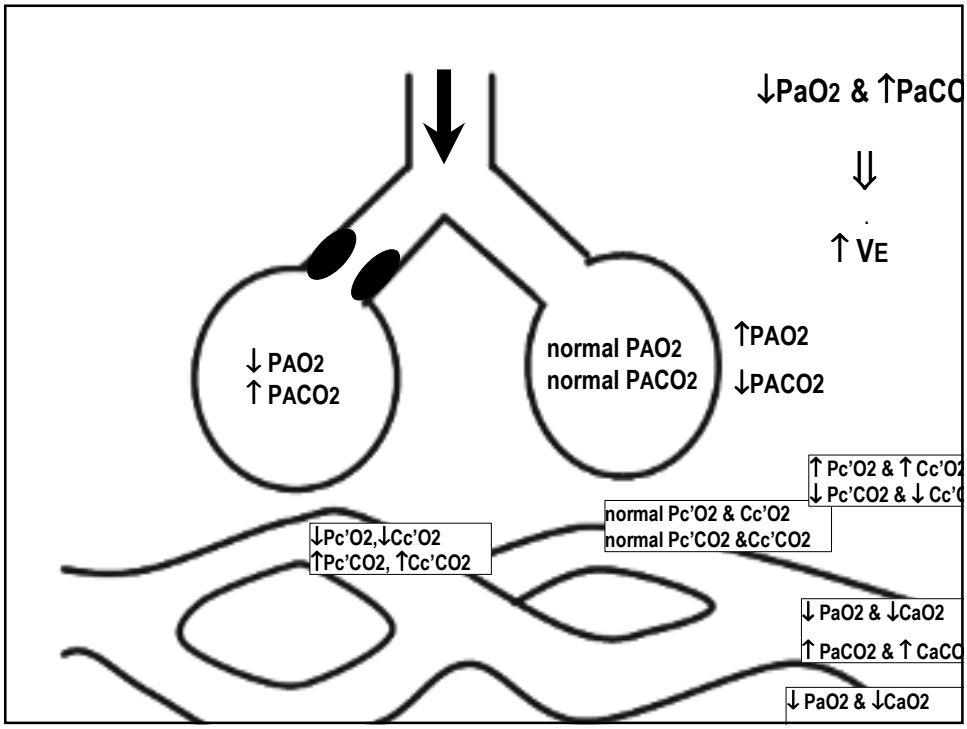
This is the most common cause of hypoxemia in disease states

NORMAL V/Q INEQUALITY FROM THE APEX TO BASE OF THE LUNGS




O2=150
CO2=0
O2=150
CO2=0
O2=40
CO2=45
O2=100
CO2=40
O2=150
CO2=0
O2=40 O2=40
CO2=45 CO2=45
O2=40 O2=100
CO2=45 CO2=40
Shunt
V/Q=0
Ideal
V/Q=1
Dead Space
V/Q=∞
zero
low V/Q
normal V/Q
high V/Q
infinity


↓ PAO2
↑ PACO2
normal PAO2
normal PACO2
↓Pc'O2,↓Cc'O2
↑Pc'CO2, ↑Cc'CO2
normal Pc'O2 & Cc'O2
normal Pc'CO2 &Cc'CO2
↓ PaO2 & ↓CaO2
↑ PaCO2 & ↑ CaCO2



5. DIFFUSION IMPAIRMENT

- $P(A\text{-}a)O_2$ normal at rest; may be increased during exercise
- $PaCO_2$ within the normal range
- a rare observation in clinical setting (elite athletes during intense exercise/severe pulmonary fibrosis during exercise)

Summary	arterial blood		venous blood			Does ↑FIO2 correct PaO2?
	PO_2	PCO_2	PO_2	PCO_2	$P(A\text{-}a)O_2$	
Hypoxemia						
Hypoventilation	↓	↑	↓	↑	normal	yes
↓ P_IO_2	↓	↓	↓	↓	normal	yes
R-L Shunt	↓	normal	↓	normal	↑	no
Diffusion defect	↓	normal	↓	normal	↑ during exercise	yes
VA/Q inequality	↓	normal	↓	normal	↑	yes
Tissue hypoxia						
Anemic hypoxia	normal	normal	↓	normal	normal	no
CO poisoning	normal	normal	↓	normal	normal	possibly
Stagnant hypoxia	normal	normal	↓	normal	normal	no
Histotoxic hypoxia	normal	normal	↑	normal	normal	no

•**Mixed causes of hypoxemia occur frequently and it is often impossible to define precisely the extent of the contribution of each mechanism in the acutely ill patient.**