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VASCULAR RESISTANCE IN THE PULMONARY CIRCULATION IS ONE-TENTH THAT OF THE SYSTEMIC CIRCULATION

WITHIN THE PULMONARY CIRCULATION, BLOOD FLOW MUST BE DIRECTED TO WELL VENTILATED (OXYGENATED) ALVEOLI, THAT IS, VENTILATION MUST BE MATCHED WITH PERFUSION
VENTILATION - PERFUSION
RELATIONSHIPS IN THE LUNG

IDEAL - $\dot{V}/\dot{Q} = 1$

$PO_2 = 40\, \text{mm Hg}$

$PO_2 = 90\, \text{mm Hg}$
VENTILATION - PERFUSION RELATIONSHIPS IN THE LUNG

IDEAL - $\dot{V}/\dot{Q} = 1$
Decreased O₂ tension

ALVEOLAR HYPOXIA!!

BLOOD FLOW IS DIVERTED

PO₂ IS MAINTAINED

HYPOXIC PULMONARY VASOCONSTRICTION

VENTILATION - PERFUSION RELATIONSHIPS IN THE LUNG
If the hypoxic reflex fails or if there are no well ventilated lung units to divert to – PO$_2$ will fall
Ventilation – Perfusion $\dot{V}/\dot{Q}$ Matching
How much oxygen is in the alveolus? What is “normal”?

To answer this question we need to review the alveolar gas equation:

\[ P_{A_O_2} = F_i O_2 (P_B - P_{H_2O}) - P_a CO_2 / R \]

Where:
- \( P_{A_O_2} \) = alveolar oxygen tension
- \( F_i O_2 \) = the fraction of inspired oxygen
- \( P_B - P_{H_2O} \) = barometric – water vapor pressure
- \( P_a CO_2 \) = arterial carbon dioxide tension
- \( R \) = the respiratory quotient
How much oxygen is in the alveolus? What is “normal”?

To answer this question we need to review the alveolar gas equation: \[ P_{A\text{O}_2} = F_{i\text{O}_2}(P_B-P_{H_2O}) - P_{a\text{CO}_2} / R \]

So: \[ P_{A\text{O}_2} = 0.21 (760 \text{ mm Hg} - 47\text{mm Hg}) - 40\text{mm Hg} / 0.8 \]

Thus: \[ P_{A\text{O}_2} = 99 \text{ mm Hg} \]

“normal” \( P_{A\text{O}_2} \) is approximately 99 mm Hg

The Sprague modification of the alveolar gas equation (room air only): \[ 150 - P_{a\text{CO}_2} \times 1.25 \]
How much oxygen is in the alveolus? How much is in the arterial blood?

What is the alveolar – arterial oxygen difference (A-aDO₂)?

What are “normal” blood gas values?

pH = 7.35 to 7.45 units
PCO₂ = 35 to 45 mm Hg
PO₂ = >85 to 90

So what is the normal A-aDO₂? 10 to 15 mm Hg

ON ROOM AIR
Case # 1:

How do you approach the problem?

The answer begins with Dalton’s gas laws:

#1; the pressure of a mixture of gasses equals the sum of the partial pressures of the constituent gasses.

#2; so long as no chemical change occurs, each gas in a mixture of gasses is absorbed by a given volume of solvent in proportion not to the local pressure of the mixture, but to the partial pressure of that gas.
Case # 1:

What does that mean?

#1; the pressure of a mixture of gasses equals the sum of the partial pressures of the constituent gasses.

In the alveolus, the mixture of gasses contains nitrogen, water vapor, trace gasses, oxygen and carbon dioxide.

At the end of a breath, the pressure in the alveolus = atmospheric pressure.

So.. \( P_B = P_{N_2} + P_{H_2O} + P_{\text{trace gasses}} + P_{O_2} + P_{CO_2} \)

Or.. \( P_{O_2} + P_{CO_2} = \text{a constant} \)
Case # 1:

What does that mean?

If $\text{PO}_2 + \text{PCO}_2 = \text{a constant}$, then what can we conclude would occur if the alveoli are inadequately ventilated?

In the case of alveolar hypoventilation, what happens to the $\text{PCO}_2$? How do we detect this?

If $\text{PO}_2 + \text{PCO}_2 = \text{a constant}$, then what happens if $\text{PCO}_2$ increases?

How do you determine if the increase in $\text{PCO}_2$ explains the measured decrease in $\text{PO}_2$?
SOLVE THE ALVEOLAR GAS EQUATION!

\[ P_AO_2 = F_iO_2(P_B-P_{H2O}) - P_aCO_2 / R \]

So: \[ P_AO_2 = 0.21 \times (760 \text{ mm Hg} - 47 \text{ mm Hg}) - 60 \text{ mm Hg} / 0.8 \]

Thus, under the best possible conditions:

\[ P_AO_2 = 74 \text{ mm Hg} \]

The animal’s: \[ P_aO_2 = 66 \text{ mm Hg}, \text{ so what is the AaDO}_2? \]

The \[ AaDO_2 = 74 - 66 \text{ or } 8 \text{ mm Hg} \]

So what can you do to save the animal?
Case # 2:

How do you approach the problem?

The answer begins with the alveolar gas equation:

\[ P_{A}O_2 = F_iO_2(P_B-P_{H2O}) - P_aCO_2 / R \]

So:

\[ P_{A}O_2 = 0.21 \times (760 \text{ mm Hg} - 47\text{mm Hg}) - 50 \text{ mm Hg/ 0.8} \]

\[ P_{A}O_2 = 87 \text{ mm Hg} \]

The animal’s: \( P_aO_2 = 50 \text{ mm Hg} \), so what is the AaDO₂?

The AaDO₂ = 87 – 50 or 37 mm Hg

Does decreased alveolar ventilation explain some or all of the observed reduction in \( P_aO_2 \)?
Something else is going on here! How would you figure it out?

Maybe we have a problem with the distribution of blood flow in the lung, i.e., ventilation and perfusion are poorly matched. How would you approach that question?
The concept of VENOUS ADMIXTURE

Venous admixture is said to occur when blood passes through the lung without being properly oxygenated.

To let us use this idea, I propose that you consider Venous admixture to be divided into two types.

These are termed V/Q MISMATCH and SHUNT

Lets see which applies to our case
V/Q = 1

optimal
COMPENSATION

V/Q = 1

V/Q = 1
V/Q MISMATCH

WHAT IF BLOOD FLOW DIVERSION FAILS?

V/Q > 1

V/Q < 1
Ventilation – Perfusion $\dot{V}/\dot{Q}$ Matching

![Graph](image-url)
Ventilation – Perfusion $\dot{V}/\dot{Q}$ Mismatch
How would confirm that this is the mechanism responsible for the reduced oxygen tension in this case?

What therapy would you employ?

Provide a small amount of supplemental oxygen for the animal.
V/Q MISMATCH

A

V/Q > 1

B

V/Q < 1

Response to supplemental oxygen
alveolus B
alveolus A
arterial point

\( \% \text{ Hb SATURATION} \)

\( P_{O_2} \text{ (mmHg)} \)

\( \text{TOTAL } O_2 \)

\( \text{DISSOLVED } O_2 \)

\( O_2 \text{ CONCENTRATION (ml/100ml)} \)
Case # 3:

How do you approach the problem?

Do you need the alveolar gas equation:

\[ P_{A\,O_2} = F_iO_2(P_B-P_{H_2O}) - P_{a\,CO_2} / R \]

Does decreased alveolar ventilation explain some or all of the observed reduction in \( P_{a\,O_2} \)?
Something else is going on here! How would you figure it out?

Maybe we have a problem with the distribution of blood flow in the lung, i.e., ventilation and perfusion are poorly matched. How would you approach that question?
The concept of VENOUS ADMIXTURE

Venous admixture is said to occur when blood passes through the lung without being properly oxygenated.

To let us use this idea, I propose that you consider venous admixture to be divided into two types.

These are termed V/Q MISMATCH and SHUNT

Let's see which applies to our case.
optimal

V/Q = 1  V/Q = 1
WHAT IF BLOOD FLOW DIVERSION FAILS?

V/Q > 1

V/Q < 0

SHUNT
How would confirm that this is the mechanism responsible for the reduced oxygen tension in this case?

What therapy would you employ?

Provide supplemental oxygen for the animal - 80% oxygen via mechanical ventilator.
Response to supplemental oxygen

A: V/Q > 1
B: V/Q < 0
Oh great, what do you do now?

Can we convert shunt to V/Q mismatch? If so, how?

Positive end expiratory pressure – AKA; PEEP
Response to PEEP and supplemental oxygen

SHUNT is converted to V/Q mismatch

V/Q > 1

V/Q < 1
RESPONSE TO SUPPLIMENTAL OXYGEN – WHY PEEP IS SO VALUABLE

SHUNT

V/Q MISMATCH (SHUNT + PEEP)