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Alveolar Ventilation II

M1 – Cardiovascular/Respiratory Sequence

Louis D'Alecy, Ph.D.

Fall 2008

Monday 11/17/08, 10:00

20 slides, 50 minutes

1. Alveolar Ventilation
2. Composition of gases
3. A-a gradient
4. Measurement of ventilation

Composition of Alveolar Gas

What do we breath?	**Air +/- moisture**
What do we breath in?	**Air & moisture (37°C)**
What do we breath out?	**Air, CO_2 & H_2O**
What is air made of?	**N_2 and O_2 mostly**
How determine composition?	**Partial Pressure of O_2**

Partial pressure of a gas is equal to its fractional concentration times the total pressures of all gases in mixture. (Dalton's Gas Law)

So why alveolar PO_2 so low??

Dry air

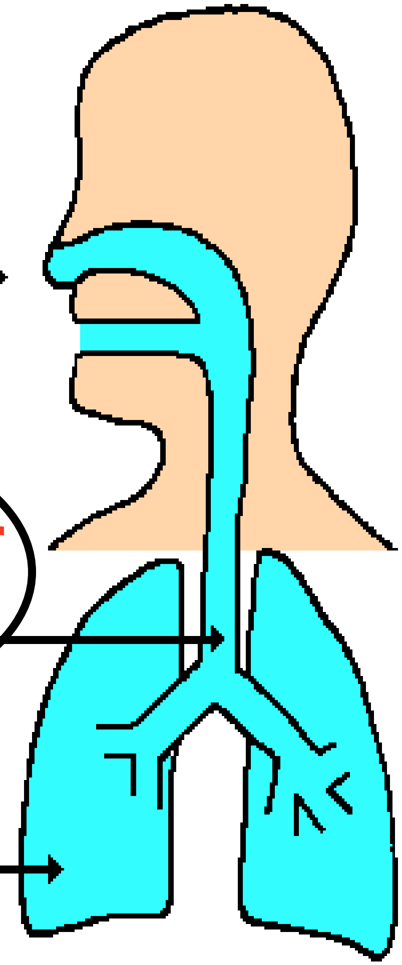
$P_{bO_2} = \% O_2 \; P_b = 160$ mm Hg

Humidified air

$P_{IO_2} = \% O_2 (P_b - P_{H20}) = 0.21 \times 713 = 150$ mm Hg

$P_{AO_2} = 104$ mm Hg

??Alveolar air partial pressure of oxygen ??



Inspire = “just add water” but…

Dry Atmospheric Gas at Standard Barometric Pressure	
P_{O_2}	159.0 mm Hg
P_{CO_2}	0.3 mm Hg
P_{N_2}	600.6 mm Hg

} = **760 mmHg**

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Inspired Gas at Standard Barometric Pressure	
PI_{O_2}	149.0 mm Hg
PI_{CO_2}	0.3 mm Hg
PI_{N_2}	564.0 mm Hg
PI_{H_2O}	47.0 mm Hg

} **760**

Adding water dilutes all the other gases.

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Humidified!

Mix in CO_2 in alveolus

Inspired Gas at Standard Barometric Pressure	
PI_{O_2}	149.0 mm Hg
PI_{CO_2}	0.3 mm Hg
PI_{N_2}	564.0 mm Hg
PI_{H_2O}	47.0 mm Hg

} = 760 mmHg

Mixed !

Alveolar Gas at Standard Barometric Pressure	
PA_{O_2}	104 mm Hg
PA_{CO_2}	40 mm Hg
PA_{N_2}	569 mm Hg
PA_{H_2O}	47 mm Hg

} 760

Adding CO_2 dilutes the other gases (except water) .

Mix Alveolar with "inspired"

Alveolar Gas at Standard Barometric Pressure	
$P_{A_{O_2}}$	104 mm Hg
$P_{A_{CO_2}}$	40 mm Hg
$P_{A_{N_2}}$	569 mm Hg
$P_{A_{H_2O}}$	47 mm Hg

}=760 mmHg

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Expired air has more O_2 than alveoli!!!!

Mixed Expired Air at Standard Barometric Pressure	
$P_{E_{O_2}}$	120 mm Hg
$P_{E_{CO_2}}$	27 mm Hg
$P_{E_{N_2}}$	566 mm Hg
$P_{E_{H_2O}}$	47 mm Hg

}=760 mmHg

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Expired

O_2 goes up and CO_2 goes down.

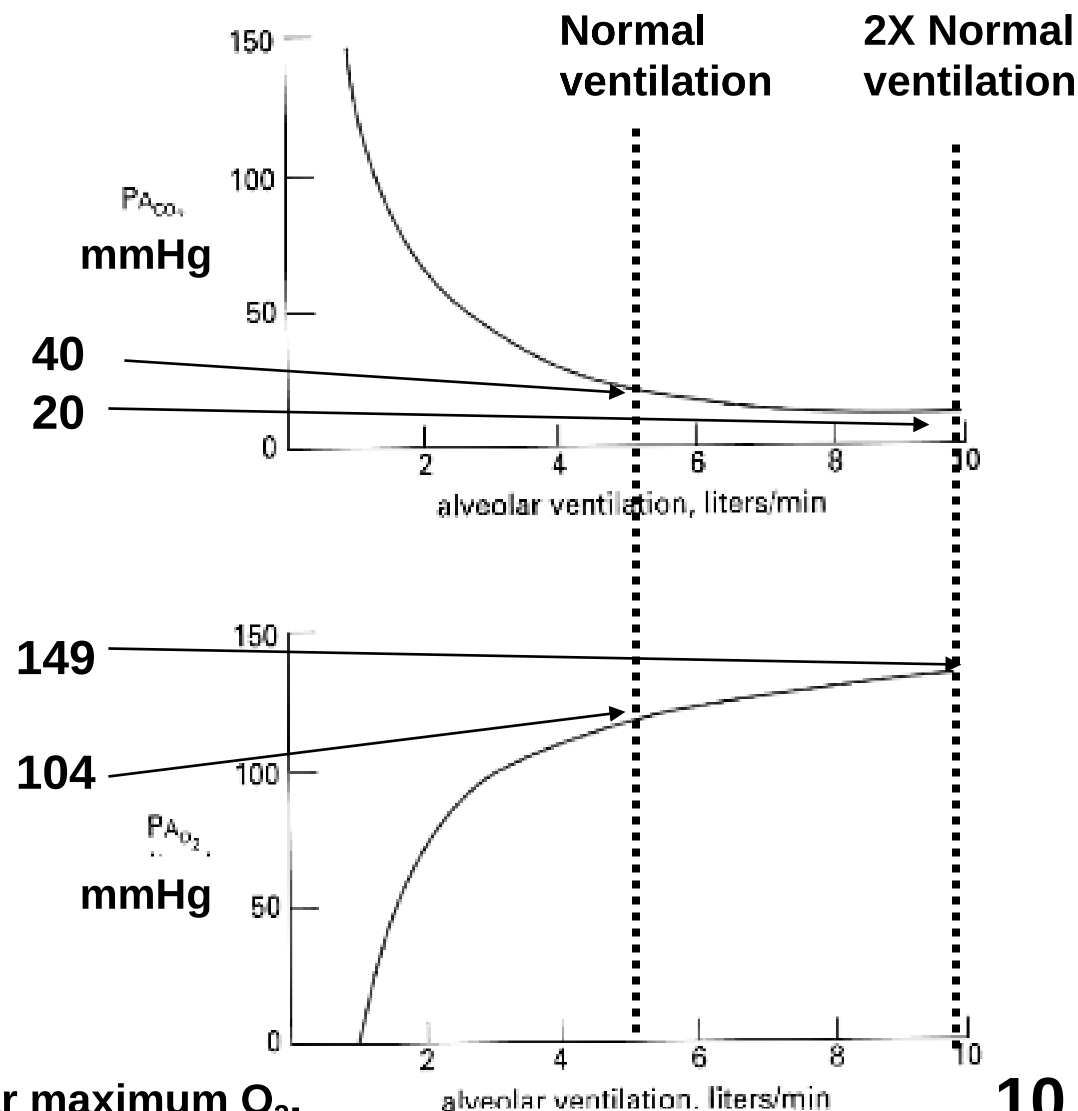
Doubling Ventilation changes alveolar gas

Decreases P_{CO2} 50%
from 40 to 20 mmHg.

Reduces CO_2 content 50%. Later

Increases P_{O2}
But not double
from 104 to 149 mmHg.

Little effect on O_2 content.
Later- blood already carrying near maximum O_2.



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Ventilation changes alveolar gas

Previous figure deceptive.

2X $\dot{V}_A$ **= 1/2** PA_{CO2} **CO_2 from 40 to 20 mmHg and blood CO_2 content decreases significantly**

But

2X $\dot{V}_A$ **=** PA_{O2} **goes from 104 toward 149 mmHg as you are approaching the PO_2 of inspired air but the blood O_2 content does not increase substantially because arterial blood is almost 100% saturated at PO_2 of 100mmHg.**

TRANSPORT AND CONTENT NEXT HOUR

Main Functions of Respiratory System

1. Delivers oxygen to blood
2. Eliminates carbon dioxide from blood
3. Regulates blood pH

But how do you know if it working?

Alveolar ventilation and (A-a) gradient

If blood PO_2 and or PCO_2 is not normal
how do we know if the lungs are working
or if there is another problem?
We need to know:

1) Is there adequate Alveolar ventilation?
And/Or
2) Is there an abnormally high Alveolar-arterial (A-a) gradient or is there a right-to-left shunt?

V/Q mismatches and shunts Dr. Sisson on Tuesday and Wednesday.

Normal (A-a) gradient = 10 mmHg

Alveolar O_2 > Arterial O_2

Why?

-**anatomic shunts (or physiologic shunts, 2-5%): some venous blood gets directly into arterial circulation as in bronchial veins, pleural veins, thebesian veins (coronary).**

-**true (absolute) shunts: (non-ventilated alveoli)**

- **"shunt-like states" (V/Q mismatches) (later)**

- **heart defects (patent foramen oval)**

The Alveolar-arterial Gradient

How do we know if the lungs working?

Is the oxygen getting to the Alveoli
and then
into the blood?
Need to know:

1. Arterial blood oxygen partial pressure (PaO_2).
Measure blood sample. = "a"

2. Alveolar oxygen partial pressure.
*****Calculate using "Alveolar Gas Equation".**

Alveolar Gas Equation

to calculate alveolar partial pressure O_2 to know if O_2 is getting into the lungs.

Assumed same as arterial CO_2.

$$P_{A_{O_2}} = F_{I_{O_2}} (P_B - P_{H_2O}) - \frac{P_{A_{CO_2}}}{R}$$

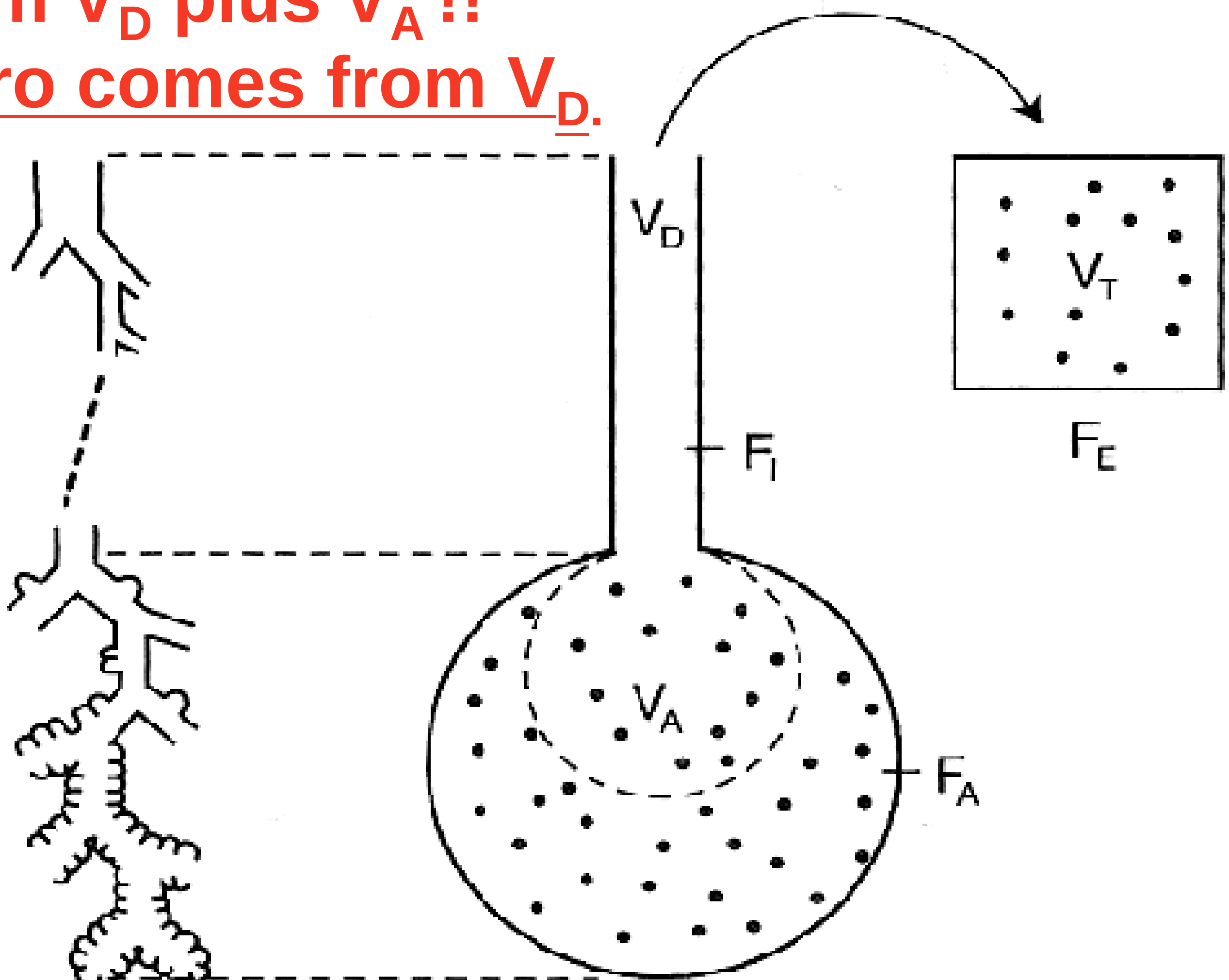
$$R = \text{respiratory exchange ratio, } \frac{\dot{V}_{CO_2}}{\dot{V}_{O_2}}$$

Alveolar O_2 = what you inspire less what you consume to CO_2.

How to Assess Alveolar Ventilation? 1of 4

ANS. = USE CO_2

All expired CO_2 comes from V_D plus V_A !!
<u>But zero comes from V_D.</u>



Expired CO_2

Source Undetermined

Assess Alveolar Ventilation 2 of 4

$$\dot{V}_{ECO2} = \dot{V}_A \times F_{A\,CO2}$$

CO_2 expired = alveolar ventilation X alveolar fraction CO_2.

Since

$$F_{A\,CO2} \propto \frac{\dot{V}_{CO2}}{\dot{V}_A}$$

$$\frac{CO_2 \text{ produced}}{\text{Alveolar vent}}$$

But

$$F_{A\,CO2} \times (P_B - P_{H2O}) = P_{ACO2}$$

Then

$$P_{ACO2} \propto \frac{\dot{V}_{CO2}}{\dot{V}_A}$$

Assess Alveolar Ventilation 3 or 4

$$P_{ACO2} \propto \frac{\dot{V}_{CO2}}{\dot{V}_A}$$

The word equation for this is:

The partial pressure of carbon dioxide in the alveolus (P_{ACO2}) tends to be **Directly** proportional to the production of carbon dioxide and **Inversely** proportional to alveolar ventilation.

If you rearrange the terms Alveolar ventilation tends to be **Directly** proportional to the production of carbon dioxide and **Inversely** proportional to (P_{ACO2}) .

Assess Alveolar Ventilation 4 of 4

Alveolar CO_2 assumed to be in equilibration with arterial blood (and assumed to be same as "end-expiratory" CO_2).

Therefore if you measure CO_2 produced and arterial CO_2 (by using arterial CO2) you can "calculate"(assess)

alveolar ventilation.

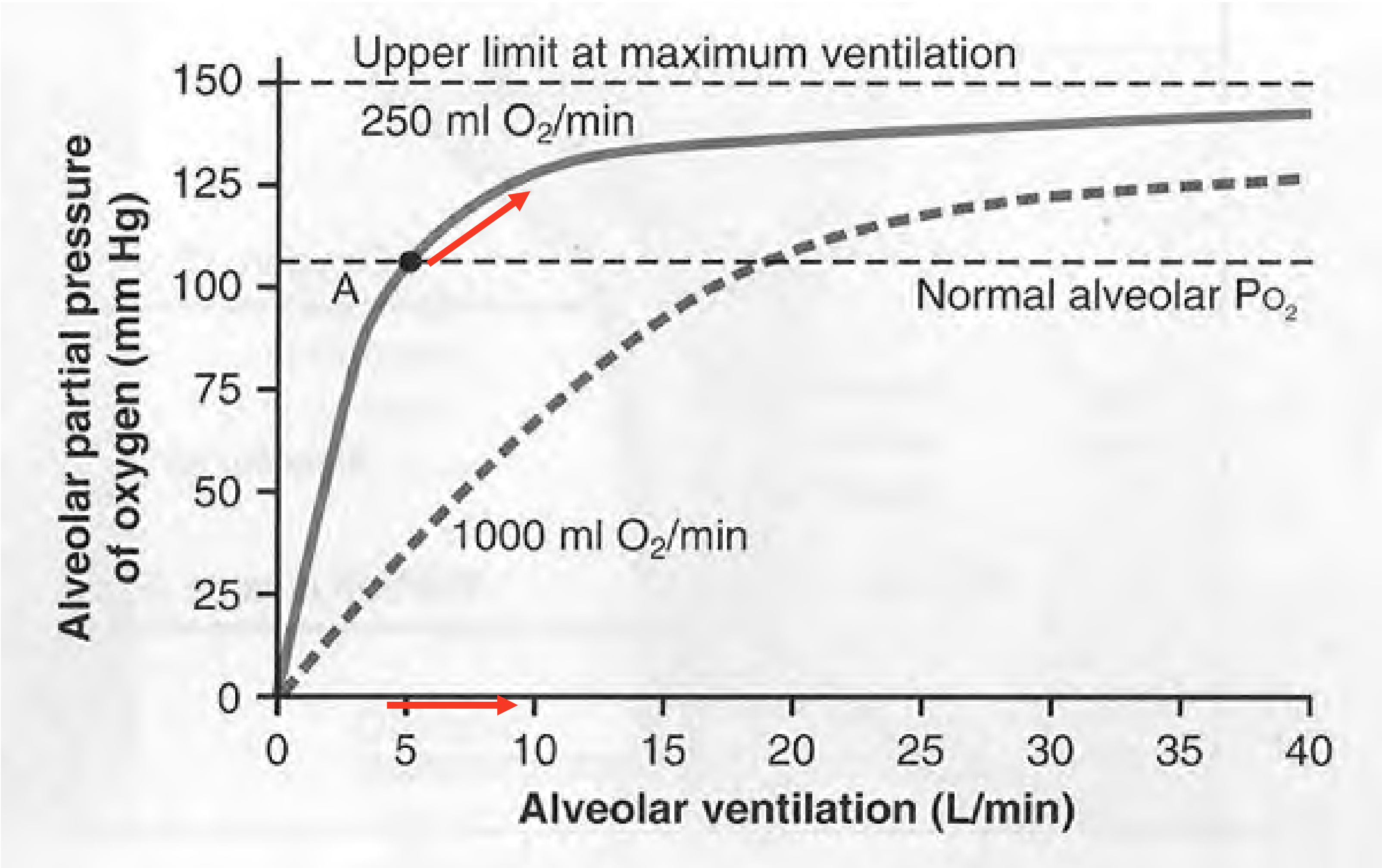
$$P_{ACO2} \propto \frac{\dot{V}_{CO2}}{\dot{V}_A} \xrightarrow{\text{Rearrange}} \dot{V}_A \propto \frac{\dot{V}_{CO2}}{P_{ACO2}}$$

How do we know if the lungs working?

By determining if oxygen
is getting to the alveoli (alveolar ventilation)
and then into the blood (A-a gradient).
(e.g. The higher the A-a gradient the
less O2 is getting into the blood.)

By determining alveolar ventilation by measuring
CO_2 produced and arterial CO_2.
(e.g. The higher the arterial CO_2 the lower the Alveolar ventilation.)

Ventilation on PA_{O2}



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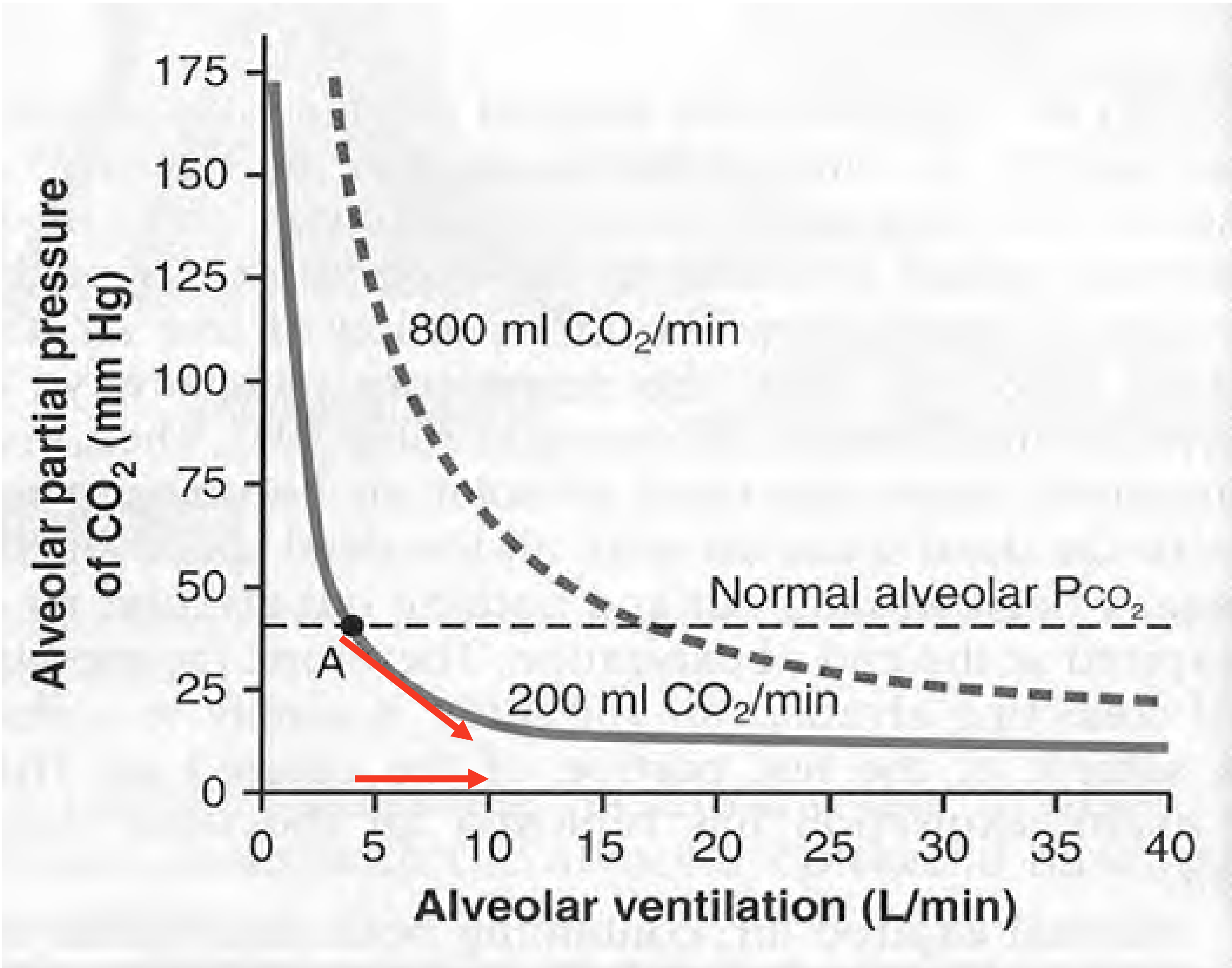
Ventilation on PA_{CO2}



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