Use + Share + Adapt

{ Content the copyright holder, author, or law permits you to use, share and adapt. }

Public Domain – Government: Works that are produced by the U.S. Government. (USC 17 § 105)
Public Domain – Expired: Works that are no longer protected due to an expired copyright term.
Public Domain – Self Dedicated: Works that a copyright holder has dedicated to the public domain.
Creative Commons – Zero Waiver
Creative Commons – Attribution License
Creative Commons – Attribution Share Alike License
Creative Commons – Attribution Noncommercial License
Creative Commons – Attribution Noncommercial Share Alike License
GNU – Free Documentation License

Make Your Own Assessment

{ Content Open.Michigan believes can be used, shared, and adapted because it is ineligible for copyright. }

Public Domain – Ineligible: Works that are ineligible for copyright protection in the U.S. (USC 17 § 102(b)) *laws in your jurisdiction may differ

{ Content Open.Michigan has used under a Fair Use determination. }

Fair Use: Use of works that is determined to be Fair consistent with the U.S. Copyright Act. (USC 17 § 107) *laws in your jurisdiction may differ

Our determination DOES NOT mean that all uses of this 3rd-party content are Fair Uses and we DO NOT guarantee that your use of the content is Fair.

To use this content you should do your own independent analysis to determine whether or not your use will be Fair.
Alveolar Ventilation II

M1 – Cardiovascular/Respiratory Sequence
Louis D’Aleyce, 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, \( \text{CO}_2 \) & \( \text{H}_2\text{O} \)
What is air made of? \( \text{N}_2 \) and \( \text{O}_2 \) mostly
How determine composition? Partial Pressure of \( \text{O}_2 \)

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

$P_{bO_2} = \% O_2 \cdot P_b = 0.21 \times 713 = 150 \text{ mm Hg}$

Humidified air

$P_{\text{O}_2} = \% O_2 \cdot (P_b - P_{H_2O}) = 0.21 \times 713 = 150 \text{ mm Hg}$

$P_{A\text{O}_2} = 104 \text{ mm Hg}$

??Alveolar air partial pressure of oxygen ??
Inspire = “just add water” but…

Adding water dilutes all the other gases.

Dry Atmospheric Gas at Standard Barometric Pressure

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{O_2}$</td>
<td>159.0 mm Hg</td>
</tr>
<tr>
<td>$P_{CO_2}$</td>
<td>0.3 mm Hg</td>
</tr>
<tr>
<td>$P_{N_2}$</td>
<td>600.6 mm Hg</td>
</tr>
</tbody>
</table>

\[ \{ \begin{align*} P_{O_2} + P_{CO_2} + P_{N_2} & = 760 \text{ mmHg} \\ \end{align*} \]

Inspired Gas at Standard Barometric Pressure

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{I_{O_2}}$</td>
<td>149.0 mm Hg</td>
</tr>
<tr>
<td>$P_{I_{CO_2}}$</td>
<td>0.3 mm Hg</td>
</tr>
<tr>
<td>$P_{I_{N_2}}$</td>
<td>564.0 mm Hg</td>
</tr>
<tr>
<td>$P_{I_{H_2O}}$</td>
<td>47.0 mm Hg</td>
</tr>
</tbody>
</table>

\[ \{ \begin{align*} P_{I_{O_2}} + P_{I_{CO_2}} + P_{I_{N_2}} + P_{I_{H_2O}} & = 760 \text{ mmHg} \\ \end{align*} \]

Humidified!
Mix in CO₂ in alveolus

Adding CO₂ dilutes the other gases (except water).

\[ \text{Mixed!} \]
Mix Alveolar with “inspired”

### Alveolar Gas at Standard Barometric Pressure

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{A_{O2}}$</td>
<td>104 mm Hg</td>
</tr>
<tr>
<td>$P_{A_{CO2}}$</td>
<td>40 mm Hg</td>
</tr>
<tr>
<td>$P_{A_{N2}}$</td>
<td>569 mm Hg</td>
</tr>
<tr>
<td>$P_{A_{H2O}}$</td>
<td>47 mm Hg</td>
</tr>
</tbody>
</table>

=760 mmHg

Expired air has more $O_2$ than alveoli!!!!

### Mixed Expired Air at Standard Barometric Pressure

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{E_{O2}}$</td>
<td>120 mm Hg</td>
</tr>
<tr>
<td>$P_{E_{CO2}}$</td>
<td>27 mm Hg</td>
</tr>
<tr>
<td>$P_{E_{N2}}$</td>
<td>566 mm Hg</td>
</tr>
<tr>
<td>$P_{E_{H2O}}$</td>
<td>47 mm Hg</td>
</tr>
</tbody>
</table>

=760 mmHg

Expired

$O_2$ goes up and $CO_2$ goes down.
Doubled Ventilation changes alveolar gas

Decreases $P_{CO_2}$ by 50% from 40 to 20 mmHg.

Reduces CO$_2$ content by 50%.

Later

Increases $P_{O_2}$ but not double from 104 to 149 mmHg.

Little effect on $O_2$ content.

Later- blood already carrying near maximum $O_2$. 

Source Undetermined
Ventilation changes alveolar gas

Previous figure deceptive.

\[ 2X V_A = \frac{1}{2} P_{A_{CO_2}} \] CO₂ from 40 to 20 mmHg and blood CO₂ content decreases significantly

But

\[ 2X V_A = P_{A_{O_2}} \] goes from 104 toward 149 mmHg as you are approaching the PO₂ of inspired air but the blood O₂ content does not increase substantially because arterial blood is almost 100% saturated at PO₂ 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 O₂ > Arterial O₂

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 are working?

Is the oxygen getting to the Alveoli and then into the blood?

Need to know:

1. Arterial blood oxygen partial pressure (PaO₂).
   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.

The equation is:

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

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

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

Assumed same as arterial $CO_2$. 
How to Assess Alveolar Ventilation? 1 of 4

All expired $\text{CO}_2$ comes from $V_D$ plus $V_A$!!

But zero comes from $V_D$.

ANS. = USE $\text{CO}_2$
Assess Alveolar Ventilation 2 of 4

\[ \dot{V}_{ECO2} = \dot{V}_A \times F_{A CO2} \]

\( CO_2 \) expired = alveolar ventilation \( \times \) alveolar fraction \( CO_2 \).

Since

\[ F_{A CO2} \propto \frac{\dot{V}_{CO2}}{\dot{V}_A} \]

CO\( _2 \) produced \( \frac{Alveolar \ vent}{Alveolar \ vent} \)

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

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.

\[ P_{ACO2} \propto \frac{\dot{V}_{CO2}}{V_A} \quad \text{Rearrange} \quad \dot{V}_A \propto \frac{\dot{V}_{CO2}}{P_{ACO2}} \]
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 CO₂ produced and arterial CO₂.
(e.g. The higher the arterial CO₂ the lower the Alveolar ventilation.)
Ventilation on $PA_{O_2}$
Ventilation on $PA_{CO_2}$
Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

Slide 6: Dr. L. D’Alecy
Slide 7: Source Undetermined; Source Undetermined
Slide 8: Source Undetermined; Source Undetermined
Slide 9: Source Undetermined; Source Undetermined
Slide 10: Source Undetermined
Slide 17: Source Undetermined
Slide 22: Source Undetermined
Slide 23: Source Undetermined