Lectures on respiratory physiology

Pulmonary Gas Exchange II
Key role of ventilation-perfusion ratio

Ventilation

Concentration depends on ventilation/blood flow

Blood flow
Model showing the importance of the ventilation-perfusion ratio
Effects of changing the ventilation-perfusion ratio

O₂ = 150 mm Hg
CO₂ = 0

O₂ = 40
CO₂ = 45

O₂ = 40
CO₂ = 45

O₂ = 100
CO₂ = 40

O₂ = 150
CO₂ = 0

Decreasing \( \dot{V}_A/\dot{Q} \)

Increasing \( \dot{V}_A/\dot{Q} \)
Effects of changing the ventilation-perfusion ratio
Distributions of ventilation and blood flow in the upright lung
Ventilation-perfusion ratios down the upright lung
Regional differences of gas exchange

<table>
<thead>
<tr>
<th>Vol (%)</th>
<th>$\dot{V}_A$ (l/min)</th>
<th>$\dot{Q}$</th>
<th>$\dot{V}_A/\dot{Q}$</th>
<th>$P_{O_2}$ (mm Hg)</th>
<th>$P_{CO_2}$</th>
<th>$P_{N_2}$</th>
<th>$O_2$</th>
<th>$CO_2$ conc. (ml/100 ml)</th>
<th>pH</th>
<th>$O_2$ in (ml/min)</th>
<th>$CO_2$ out (ml/min)</th>
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<tbody>
<tr>
<td>7</td>
<td>.24</td>
<td>.07</td>
<td>3.3</td>
<td>132</td>
<td>28</td>
<td>553</td>
<td>20.0</td>
<td>42</td>
<td>7.51</td>
<td>4</td>
<td>8</td>
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<tr>
<td>13</td>
<td>.82</td>
<td>1.29</td>
<td>0.63</td>
<td>89</td>
<td>42</td>
<td>582</td>
<td>19.2</td>
<td>49</td>
<td>7.39</td>
<td>60</td>
<td>39</td>
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Tuberculosis in the base of the lungs in the bat
Calcification in the apices of the lungs
Cause of an alveolar-arterial PO2 difference

\[ \text{PO}_2 = 101 \text{ mm Hg} \]
Ventilation-perfusion inequality must cause hypoxemia
Normal distribution of ventilation perfusion ratios
Distribution of ventilation-perfusion ratios in emphysema
Section of normal lung
Section of lung with severe emphysema
Distribution of ventilation-perfusion ratios in emphysema
Distribution of ventilation-perfusion ratios in chronic bronchitis.
Stages of impairment of gas exchange

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- Uneven $V_A$ and $Q$
- Fall in $PO_2$
- Rise in $PCO_2$
- Increased ventilation
Ventilation-perfusion inequality must cause hypoxemia

\[
\frac{V_A}{Q} = \frac{1}{10} \quad \frac{V_A}{Q} = \frac{10}{10} \quad \frac{V_A}{Q} = \frac{10}{1}\]

\[O_2\text{ concentration} \quad 14.6 \quad 16.0 \quad 19.5 \quad 20.0 \quad 17.9 \text{ ml/100 ml}\]
Stages of impairment of gas exchange

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How can we assess the amount of ventilation-perfusion inequality in lung disease?

Suppose the arterial PO$_2$ is 50 and the PCO$_2$ is 60 mm Hg.

Is ventilation-perfusion inequality present or is there just hypoventilation?

To answer this we use the alveolar gas equation.
Using the alveolar gas equation to calculate the alveolar-arterial $PO_2$ difference

$$P_{A\,O_2} = P_{1\,O_2} - \frac{P_{A\,CO_2}}{R} + F$$

$$P_{A\,O_2} = 149 - \frac{60}{0.8}$$

$$P_{A\,O_2} = 74 \text{ mmHg}$$

$A$ - a difference $= 74 - 50$

$A$ - a difference $= 24 \text{ mmHg}$