Oxygen & Hypoxia: Physiological Tidbits

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Overview

- Unusual cause of increased (A-a)O2 difference
- Apneic oxygenation
- Mechanisms of cardiovascular effects of hypoxia
Case Report

- 24 year old women (with perfectly normal lungs) to ED with hyperventilation syndrome. As she walks in her PaCO₂ is 24 mmHg, and PaO₂ 118 mmHg
  - (A-a)O₂=(150-24/0.8)-118=2

- MD comes to see her; less anxious; markedly decreased ventilation; apneic for 1.5 minutes
  - PaCO₂ increases to 32 mmHg;
  - PaO₂ decreases from 118 to 60 mmHg

- Calculation of (A-a)O₂: PAO₂=PIO₂-PCO₂/R
  =150-32/0.8=110;
  - Therefore (A-a)O₂=110-60=50 mmHg
What is the reason for the increased \((A-a)O_2\)

- \(P_AO_2 = P_{I}O_2 - PaCO_2 / R\)

- \(R = \text{Respiratory quotient} = VCO_2 / VO_2\)
  - \(VCO_2 = \text{CO}_2 \text{ elimination } \sim 200 \text{ ml/min}\)
  - \(VO_2 = \text{O}_2 \text{ uptake } \sim 250 \text{ ml/min}\)

\[R = \frac{200}{250} = 0.8\]
What is the Respiratory Quotient (R)?
There are 2 R’s!

\[ R_{tiss} = \frac{V_{tCO_2}}{V_{tO_2}} = \frac{200}{250} = 0.8 \]

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The 2 R’s are NOT necessarily equal in non-steady state conditions.
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In this situation, the alveolar air equation is not valid.
When are changes in R relevant?

- Changes in diet
  - Protein vs fat vs sugar
- During periods of non-steady state
  - Acute hypoventilation
  - Acute hyperventilation
- Dialysis with a non-bicarbonate buffer
  - Dialysis-associated hypoxemia
Apneic Oxygenation

- Originally called diffusion respiration (Draper and Whitehead, 1940’s)

- Technique
  - Washout of N₂ by ventilation with 100% O₂
  - 100% O₂ @ airway opening
  - adequate oxygenation for >1 hr
  - CO₂ accumulation
Apneic Oxygenation in Man
Frumin et al *Anesthesiology* 1961

- Patients in OR: AO for 45-60 minutes
- SaO2 > 95% in all patients

![Graph showing PaCO2 and pH levels for patients](image-url)
How is it possible to obtain adequate oxygenation without ventilation?

(~10% VCO₂)
(~20 ml/min)

CO₂ into tissues
(~90% VCO₂)
(~180 ml/min)
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Animals can survive ~90 minutes during Apneic Oxygenation With PO₂ ~80 mmHg
Why do animals die as apneic oxygenation continues despite adequate PaO2s?
Physiological Responses to Hypoxemia

- Cardiovascular responses to hypoxemia
  - Heart rate response
  - Respiratory sinus arrhythmia
Constant Flow Ventilation

Impact of Constant Flow Ventilation on Heart Rate Response to Hypoxia

- **Rationale:**
  - Remove effect of cyclic changes in lung volume on hemodynamics

- **Methods:**
  - Studies in dogs made hypoxic
    - Spontaneous breathing
    - Constant Flow
Heart Rate b/min vs Oxygen Saturation (SaO₂).

- Squares: SB: PaCO₂ = 30 mmHg
- Diamonds: SB: PaCO₂ = 50 mmHg
- Triangles: CFV: PaCO₂ = 30 mmHg
- Circles: CFV: PaCO₂ = 50 mmHg
Respiratory Sinus Arrhythmia

Shykoff, Naqvi, Menon, Slutsky J Clin Invest 87:1621-27, 1991
Conclusions

- Interpretation of alveolar-air equation requires a consideration of respiratory quotient
- Apneic oxygenation
  - Interesting technique with potential implications for assessing brain death and tolerance to hypercapnia
- Heart-lung interactions not simply related to impact of pressures