Cognitive Performance Alterations due to Hypoxia vs Hypocapnia

A review of the literature

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Aerospace Medical Association Annual Scientific Meeting
Chicago May 14, 2013
Disclosure Information
84th Annual AsMA Scientific Meeting

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I have the following financial relationships to disclose:

• Grant/Research support from:
  • Armasuisse

• Employee of:
  • Mayo Clinic

I will not discuss off-label use and/or investigational use in my presentation
Learning Objectives

1. Appreciate the impact of capnic status on Oxy-Hb dissociation curve
2. Understand the differential effects of capnic status on different vascular beds in the body with focus on the CNS
3. Understand the neuromuscular effects of hyperventilation
Basic Facts in Physiology: Hypoxia & Hyperventilation

• Indistinguishable symptoms, hyperventilation is a common sign of hypoxia

  Wayne, J Aviation Med 1962

• Carbon dioxide body stores:
  - Primarily tissue bound: 120 L/70kg
  - Blood: 2.7 L

• Oxygen stores:
  - 2L/70kg man
  - Primarily blood: 1.2L/70kg man
  - Lung: 0.5 L/70kg man

Physiological Review, s Cherniak 1970
Basic Facts in Physiology: Hypoxia & Hyperventilation

• Hyperventilation & Aviation
  • 10 subjects, voluntary hyperventilation
  • Doubling of RR
  • 2 subjects collapsed after 20min
  • Carpopedal spasms in 1 individual

Hinshaw C et al, J Aviation Med 1943
Historical Perspective

Video Hyperventilation
Oxygen dissociation curve of blood

% Saturation

Oxygen tension (mmHg)

Oxygen tension (mmHg):
- 27: Saturation 95%
- 40: Saturation 90%
- 50: Saturation 75%
- 95: Saturation 50%
- 100: Saturation 50%
Increase in $P_{50} = \bullet O_2$ at tissue level

- $PCO_2$
- $H^+$
- Temperature
- DPG
Decrease in $P_{50} = \cdot O_2$ at tissue level

- $PCO_2$
- $H^+$
- Temperature
- DPG

Oxygen tension vs. % Saturation

- 100
- 50

20 27 100 mmHg
Carbon dioxide and regional vascular beds

- Coronary vasodilatation
- Sympatho-adrenal drive increase
- Cutaneous vasodilatation
- Cerebral vasodilatation
- Pulmonary vasodilatation
Capnic State and Vascular Regional Responses

- Cerebral vasculature (AJNR 30:378-85, 2009):
  - Investigation of 45 patients with altered mental status
  - Tools: MRI, arterial spin labelling protocol (ASL)

Linear relationship of $pCO_2$ & cerebral perfusion

1 mmHg change in $pCO_2 = 4 \text{ ml} / 100\text{g} / \text{min}$ change in perfusion
Cerebral perfusion changes

\[ pCO_2 \ 34.4 \text{ mmHg} \]

\[ pCO_2 \ 56 \text{ mmHg} \]

(Pollock et al, AJNR 30:378-85, 2009)
Cerebral vasculature: oxygen causes vasoconstriction

Cognition & CO$_2$

• 3% CO$_2$ added in inspired air (short exposures):
  • Improved mental keenness
  • Improved psychomotor test performance
  • Sleeplessness

• 1.5% CO$_2$ over 42 days (21 individuals):
  • No change in performance on psychomotor testing  (Schaefer, Aerospace Med, 1961)
Cognitive changes & capnic state

- Free recall and capnic state
  - Normal: 36.7 mmHg
  - Hypocapnia: 32 mmHg
  - 18 students
    - Immediate recall unaffected, delayed recall compromised

Feeling lightheaded..

- Lightheadedness is initially associated with changes in CBF, then operant conditioning may play a role
  - 33 subjects, RR 30 vs 18
  - After few episodes a perceptual cognitive process may ensue that triggers perception without commensurate change in CBF

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Questions & Discussion