2018 AmSECT pediatric
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Hyperoxia – "What's it to ya"

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- **"All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a thing poison."**

- Paracelsus (1493-1541)

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What is hyperoxia

- Is it a PO_2 of:
  - 600 mmHg
  - 500 mmHg
  - 400 mmHg
  - 300 mmHg
  - 200 mmHg
  - >100 mmHg (physiologic normoxia)
  - FiO_2 of 100%

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What is hyperoxia

- Earth's Atmosphere:
  - 20.95% Oxygen
  - 78.0% Nitrogen
  - 0.038% Carbon Dioxide
  - Trace elements
- Hyperoxia – a PO_2 in the breathing environment greater than that which is found in the Earth's atmosphere at sea level

No clear definition for us

- Risks and benefits of Oxygen have been debated since its discovery in 1772.
- After 60+ years of clinical cardiopulmonary bypass experience
  - Still disagreement on optimal PO_2 on CPB.

Evidence for hyperoxia

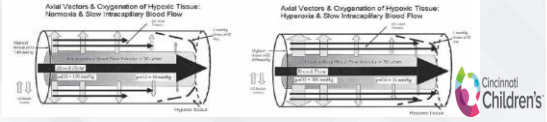
- Can lead to improved tissue oxygenation[1]
  - Especially at low hematocrit levels
- Can reduce need for transfusion[2,3]
  - Increasing PaO_2 from 150 mmHg to 500 mmHg increases O_2 delivery by approximately 10.5 ml/L
    - Equivalent to approximately 1 g/dL hemoglobin (3% Hct)

Evidence for hyperoxia

- Redistributes oxygen to locally hypoxic tissues during anemia.[3]
  - Creates margin of safety for vital organ oxygenation

Evidence for hyperoxia[4,5]

Scenario #1	Scenario #2
Blood flow = 3 L/min	Blood flow = 3 L/min
Hemoglobin = 9 gm/dl	Hemoglobin = 8 gm/dl
paO2 = **150 mmHg**	paO2 = **500 mmHg**
O2 on Hgb = 122 ml/L	O2 on Hgb = 109 ml/L
Dissolved O2 = 5 ml/L	Dissolved O2 = 15 ml/L
O2 delivery / L = 127 ml/L	O2 delivery / L = 124 ml/L
Total O2 delivery = 381 ml/min	Total O2 delivery = 372 ml/min



Extends safe DHCA time

- Hyperoxia and hypercapnia (pH stat) before DHCA[6-7]
  - Extend safe DHCA time
  - Results in least amount of acid production

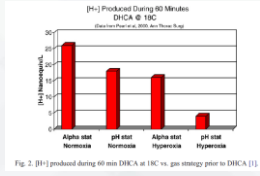
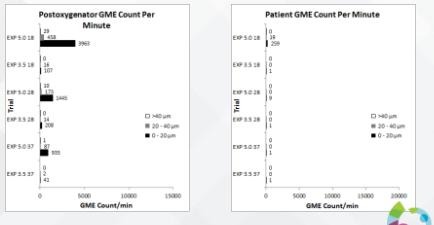


Fig. 2. [H+] produced during 60 min DHCA at 18C vs. gas strategy prior to DHCA [1].

GME reduction

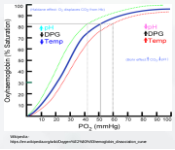
- GME reduction by nitrogen off-gassing[3,6]
  - Requires sweep gas of 100% O_2
  - Any nitrogen in gas will be replaced with oxygen as it passes through oxygenator
  - If an oxygen GME passes through oxygenator and blocks an arteriole or capillary
    - Will quickly be absorbed and the blockage removed
  - If nitrogen GME are already in place
    - Removed 10 times faster with 100% O_2 vs. room air.

Hypobaric Oxygenation[8]



Potentially Attenuates shifts in ODC

- Oxyhemoglobin dissociation curve shifts to the left during hypothermia[9]
  - P_{50} decreases – increased affinity for oxygen
  - Oxygen release to tissue is limited
  - Dissolved oxygen becomes a bigger player
  - A higher PO_2 allows more oxygen to be delivered to tissue at same hemoglobin.



Preconditioning

- Attenuate ischemia-reperfusion injury with preconditioning.[10,11]
  - Vasoconstrictive stimulus of short-term hyperoxia exposure before sustained ischemia.
  - Hyperoxia-induced vasoconstriction may counteract systemic inflammation-induced vasoplegia.[12]
    - Reduce vasopressor requirements
  - Diameter of large conduit arteries remain equal[12,13]
    - Suggests vasoconstriction mainly occurs at microvascular level

Post cardiac arrest

- Hyperoxia post-cardiac arrest[14]
  - Moderate hyperoxia (101-299 mmHg)
    - Not associated with decreased survival
    - Associated with improved organ function at 24 hours as compared to normoxia and severe hyperoxia (>300 mmHg).
    - Severe hyperoxia did result in significantly higher rates of mortality
      - Odds ratio for survival of 0.83 for every hour exposed to severe hyperoxia post-arrest

Margin of safety

- A PaO_2 higher than normoxia provides the perfusionist a margin of safety
  - Time after beginning to rewarm when consumption increases
  - Patient is being set up for extubation in the room and anesthesia is light on anesthetic

Margin of safety

- Safety event occurs unexpectedly
  - Oxygenator not working
  - Air in circuit
  - Separation of line(s)
  - Anything that might make you come off bypass unexpectedly
    - Perfusion event
    - Surgeon event

Mechanism

- Increasing FiO_2 or PO_2 does not substantially increase oxygen delivery[3]
  - Redistributes oxygen to hypoxic tissues causing the acid generation
  - Consider increasing the FiO_2 before masking the acidosis with things like Sodium Bicarbonate or a blood exposure

Use within every clinical situation is inconclusive

- Utilizing hyperoxia at the appropriate times is key
  - When are patients at greatest risk for:
    - Re-perfusion injury
    - GME generation
  - Before DHCA

Use within every clinical situation is inconclusive

- Weighing the risks and benefits for individual patients
  - Oxygen, like any drug has beneficial and adverse effects.
- We are not the only field that debate this
  - Cardiac anesthesiologists cannot agree on when, how much, and why.

Evidence against hyperoxia?

- Randomized controlled trial during bypass – CABG patients[15]
  - PaO_2 400 mmHg vs PaO_2 140 mmHg
    - Decreased cardiac index 3.3 vs 3.1 (p= 0.6)
- Randomized controlled trial during rewarming on bypass – CABG patients[16]
  - FiO_2 0.4-0.6 vs. 0.4-0.5 vs 0.35-0.45
    - Hospital length of stay – No difference

Evidence against hyperoxia?

- Randomized controlled trial before bypass for 120 min before cardioplegia – CABG patients[17]
  - FiO_2 >0.96 vs 0.4
    - Cardiac index – No difference
- Many studies compare FiO_2 values and never illustrate actual PaO_2 values.
  - An FiO_2 of 0.5 for some may be a PaO_2 of 450 mmHg and only 100 mmHg for others.

Evidence against hyperoxia?

- Other studies compare hyperoxia and "normoxia" but are still utilizing hyperoxic levels
  - i.e. 200-300mmHg vs >400 mmHg

- "Evidence is not fact, although the evidence we choose to believe guides much of what we do. Contradictory evidence is only evidence that the facts are not fully known."

  - Gary Grist, RN, CCP

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Acknowledgements

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