Hyperoxia – “What’s it to ya”
Sean Clingan, MS, CCP
Cincinnati Children’s Hospital Medical Center

No disclosures

“All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a thing poison.”
- Paracelsus (1493-1541)

What is hyperoxia
- Is it a PO₂ of:
  - 600 mmHg
  - 500 mmHg
  - 400 mmHg
  - 300 mmHg
  - 200 mmHg
  - >100 mmHg (physiologic normoxia)
  - FiO₂ of 100%
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
  - Especially at low hematocrit levels

- Can reduce need for transfusion
  - Increasing PaO$_2$ from 150 mmHg to 500 mmHg increases O$_2$ delivery by approximately 10.5 mL
  - Equivalent to approximately 1 g/dL hemoglobin (3% Hct)

Evidence for hyperoxia

- Redistributes oxygen to locally hypoxic tissues during anemia.
  - Creates margin of safety for vital organ oxygenation
Evidence for hyperoxia\textsuperscript{4,5}

<table>
<thead>
<tr>
<th>Scenario #1</th>
<th>Scenario #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood flow = 3 L/min</td>
<td>Blood flow = 3 L/min</td>
</tr>
<tr>
<td>Hemoglobin = 8 g/dL</td>
<td>Hemoglobin = 8 g/dL</td>
</tr>
<tr>
<td>( pO_2 ) = 140 mmHg</td>
<td>( pO_2 ) = 140 mmHg</td>
</tr>
<tr>
<td>( O_2 ) on Hb = 122 mL/dL</td>
<td>( O_2 ) on Hb = 109 mL/dL</td>
</tr>
<tr>
<td>Dissolved ( O_2 ) = 5 mL/l</td>
<td>Dissolved ( O_2 ) = 15 mL/l</td>
</tr>
<tr>
<td>( O_2 ) delivery ( /L ) = 127 mL/L</td>
<td>( O_2 ) delivery ( /L ) = 124 mL/L</td>
</tr>
<tr>
<td>Total ( O_2 ) delivery = 383 mL/min</td>
<td>Total ( O_2 ) delivery = 373 mL/min</td>
</tr>
</tbody>
</table>

Extends safe DHCA time

- Hyperoxia and hypercapnia (pH stat) before DHCA\textsuperscript{6-7}
  - Extend safe DHCA time
  - Results in least amount of acid production

GME reduction

- GME reduction by nitrogen off-gassing\textsuperscript{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\textsuperscript{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 \(P_O_2\) 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.
  - Hyperxia-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**
- Hyperxia 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 \(P_{O_2}\) 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 \( \text{FiO}_2 \) or \( \text{PO}_2 \) does not substantially increase oxygen delivery
  - Redistributes oxygen to hypoxic tissues causing the acid generation
  - Consider increasing the \( \text{FiO}_2 \) 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
- 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\(^{15}\)
  - \(\text{PaO}_2 \geq 400 \text{ mmHg} \) vs \(\text{PaO}_2 \geq 140 \text{ mmHg}\)
  - Decreased cardiac index: 3.3 vs 3.1 (p=0.6)

- Randomized controlled trial during rewarming on bypass – CABG patients\(^{16}\)
  - \(\text{FiO}_2 0.4-0.6 \) vs. \(0.4-0.5 \) vs \(0.35-0.45\)
  - Hospital length of stay: No difference

- Randomized controlled trial before bypass for 120 min before cardioplegia – CABG patients\(^{17}\)
  - \(\text{FiO}_2 >0.96 \) vs 0.4
  - Cardiac index: No difference

- Many studies compare \(\text{FiO}_2\) values and never illustrate actual \(\text{PaO}_2\) values.
  - An \(\text{FiO}_2\) of 0.5 for some may be a \(\text{PaO}_2\) of 450 mmHg and only 100 mmHg for others.

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
Acknowledgements

- CCHMC Perfusion staff
- Gary Grist, RN, CCP

All his outstanding work that has aided our profession

References


