Oximetry and CO-Oximetry for EMTs and First Responders

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Endorsements

This educational module has been endorsed by the following professional organizations:

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RESPIRATORY GAS PHYSIOLOGY

Respiratory Gasses

- Normal Atmospheric Gasses:
  - Oxygen (O₂)
  - Carbon Dioxide (CO₂)
  - Nitrogen (N₂)
  - Water Vapor (H₂O)
  - Trace gases:
    - Argon (Ar)
    - Neon (Ne)
    - Helium (He)

Most important respiratory gases:
- Oxygen (O₂)
- Carbon Dioxide (CO₂)
Atmospheric Gasses

<table>
<thead>
<tr>
<th>GAS</th>
<th>PRESSURE (mm Hg)</th>
<th>PERCENTAGE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N₂)</td>
<td>593.408</td>
<td>78.08</td>
</tr>
<tr>
<td>Oxygen (O₂)</td>
<td>159.220</td>
<td>20.95</td>
</tr>
<tr>
<td>Argon (Ar)</td>
<td>7.144</td>
<td>0.94</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>0.288</td>
<td>0.03</td>
</tr>
<tr>
<td>Neon (Ne)</td>
<td>0.013</td>
<td>0.0018</td>
</tr>
<tr>
<td>Helium (He)</td>
<td>0.003</td>
<td>0.0005</td>
</tr>
<tr>
<td>TOTAL</td>
<td>760</td>
<td>100</td>
</tr>
</tbody>
</table>

† = dry air at sea level.

Respiratory Gasses

<table>
<thead>
<tr>
<th>GAS</th>
<th>Atmospheric Air (mm Hg)</th>
<th>%</th>
<th>Humidified Air (mm Hg)</th>
<th>%</th>
<th>Alveolar Air (mm Hg)</th>
<th>%</th>
<th>Expired Air (mm Hg)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂</td>
<td>597.0</td>
<td>78.6</td>
<td>593.4</td>
<td>78.4</td>
<td>569.0</td>
<td>74.8</td>
<td>566.0</td>
<td>74.7</td>
</tr>
<tr>
<td>O₂</td>
<td>159.0</td>
<td>20.8</td>
<td>149.3</td>
<td>19.7</td>
<td>104.0</td>
<td>13.6</td>
<td>120.0</td>
<td>15.7</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.3</td>
<td>0.04</td>
<td>0.3</td>
<td>0.04</td>
<td>40.0</td>
<td>5.3</td>
<td>27.0</td>
<td>3.5</td>
</tr>
<tr>
<td>H₂O</td>
<td>3.7</td>
<td>0.50</td>
<td>47.0</td>
<td>6.2</td>
<td>47.0</td>
<td>6.2</td>
<td>47.0</td>
<td>6.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>760</td>
<td>100</td>
<td>760</td>
<td>100</td>
<td>760</td>
<td>100</td>
<td>760</td>
<td>100</td>
</tr>
</tbody>
</table>

Oxygen

- Odorless.
- Tasteless.
- Colorless.
- Supports combustion.
- Present in the atmosphere as a diatomic gas (O₂).
- Necessary for animal life.
Oxygen

- Derived from plant photosynthesis:
  - Algae (75%).
  - Terrestrial Plants (25%).
- Oxygen atom must share electrons for stability.

Carbon Dioxide

- Colorless.
- Sour taste at high concentrations.
- Found in very low concentrations in fresh air.
- Asphyxiant.

Carbon Dioxide

- Waste product of animal life (carbohydrate and fat metabolism).
- Contains 2 atoms of oxygen and 1 atom of carbon.
Abnormal Respiratory Gasses

- Carbon monoxide (CO)

Carbon Monoxide

- Colorless
- Odorless
- Tasteless
- Results from incomplete combustion of carbon-containing compounds.
- Heavier than air.

Hemoglobin

- Protein-Iron Complex.
- Transports oxygen to peripheral tissues.
- Removes a limited amount of carbon dioxide from the peripheral tissues.
Hemoglobin Binding Sites

Hemoglobin

- The binding of oxygen changes the conformation (shape) of the hemoglobin molecule.
- Deoxyhemoglobin is converted to oxyhemoglobin.

Respiratory Gas Measurement

- Arterial Blood Gas Sampling
- Pulse Oximetry
- CO-Oximetry
Arterial Blood Gasses

- Gold standard for respiratory gas monitoring.
- Invasive
- Expensive
- Painful
- Difficult

Arterial Blood Gasses

- Excellent diagnostic tool.
- Impractical in the prehospital setting.

Parameter | Normal
---|---
pH | 7.35-7.45
PO₂ | 80-100 mm Hg
PCO₂ | 35-45 mm Hg
HCO₃⁻ | 22-26 mmol/L
BE | -2 - +2
SaO₂ | > 95%

OXYGEN MONITORING
Pulse Oximetry
- Introduced in early 1980s.
- Non-invasive measurement of oxygen saturation.
- Safe
- Inexpensive

How it works:
- Probe is placed over a vascular bed (finger, earlobe).
- Light-emitting diodes (LEDs) emit light of two different wavelengths:
  - Red = 660 nm
  - Infrared = 940 nm

Some light is absorbed by:
- Arterial blood
- Venous blood
- Tissues

Light that passes through the tissues is detected by a photodetector.
Pulse Oximetry and CO-Oximetry

Pulse Oximetry

- Only inflow of blood is used to determine SpO₂.
- Hence the name “Pulse Oximetry”
- Hb and HbO₂ absorb light and different rates due to color and conformation.

Pulsatile Flow

This is the band used to measure SpO₂.
Oximetry Probe Placement

- Finger
- Earlobe
- Heel (neonates)

Accuracy falls when LEDs and photoreceptors poorly aligned.
Accuracy decreases with lower pulse oximetry readings.

Pulse Oximetry

- Some manufacturers use reflective oximetry for monitoring.
- LEDs and photodetectors in same electrode.
- Light reflected from tissues and detected by photodetectors and findings interpreted by the software in the oximeter.
- Can be used on forehead or back.
Pulse Oximetry

- HbO₂ absorbs more infrared light than Hb.
- Hb absorbs more red light than HbO₂.
- Difference in absorption is measured.
- Ratio of absorbance matched with SpO₂ levels stored in the microprocessor.

Perfusion Index

- Reflects the pulse strength at the monitoring site.
- Ranges from 0.02% (very weak pulse strength) to 20% (very strong pulse strength).
- Helps determine best site to place probe.

Pulse Oximetry

SaO₂ or SpO₂?

- SaO₂ used for oxygen saturation readings derived from arterial blood gas analysis.
- SpO₂ used for oxygen saturation readings from pulse oximetry.
- SpO₂ and SaO₂ are normally very close.
Pulse Oximetry

- Pulse oximetry tells you:
  - SpO₂
  - Pulse rate

- Pulse oximetry cannot tell you:
  - O₂ content of the blood
  - Amount of O₂ dissolved in blood
  - Respiratory rate or tidal volume (ventilation)
  - Cardiac output or blood pressure.

Who Should Use?

- Any level of prehospital care provider who administers O₂.
  - First Responders
  - EMTs
  - EMT-Intermediates
  - Paramedics

Prehospital Indications

1. Monitor the adequacy of arterial oxyhemoglobin saturation (SpO₂)
2. To quantify the SpO₂ response to an intervention.
3. To detect blood flow in endangered body regions (e.g., extremities)
**Limitations**

- Oximetry is NOT a measure of ventilation (EtCO₂ a better measure of ventilation).
- Oximetry may lag behind hypoxic events.
- Oximetry is not a substitute for physical examination.
- Very low saturation states may be inaccurate due to absence of measured SpO₂ levels in the database.

**First-Generation Oximeter Problems**

- False Readings:
  - Hypotension.
  - Hypothermia.
  - Vasoconstriction.
  - Dyes/pigments (e.g., nail polish).
  - Movement may cause false reading in absence of pulse.
- Abnormal hemoglobin:
  - COHb.
  - METHb.
- Oximeter can’t perform:
  - Bright ambient lighting.
  - Shivering.
  - Helicopter transport.

**First-Generation Oximeter Problems**

- Motion, noise, and low perfusion states can cause artifacts and false oximetry readings.
- These have been eliminated or minimized in second-generation oximeters.
Second-Generation Technology

- Newer technology uses signal processing to minimize artifacts and false readings:
  - Adaptive Filters
  - Signal Processing Algorithms
  - Improved Sensors

Second-Generation Technology

- Technology prevents:
  - Motion artifact.
  - False readings during low-flow states.
  - False bradycardias.
  - False hypoxemias.
  - Missed desaturations.
  - Missed bradycardias.
  - Data dropouts.
  - Effects of dyshemoglobins.

Myths

- Age affects SpO2
- Gender affects SpO2
- Anemia affects SpO2
- SpO2 inaccurate in dark-skinned individuals.
- Jaundice affects SpO2.
Prehospital Usage
- Assure scene safety.
- Initial assessment.
- ABCs
- Apply oxygen when appropriate (either with or after oximetry).
- Secondary Assessment
- Ongoing monitoring.

Always treat the patient and not the oximeter.

Reading the Oximeter
- SpO₂ (%)
- PI (%)
- Pulse Rate (bpm)
- Signal Strength
What Does it Mean?

<table>
<thead>
<tr>
<th>SpO₂ READING (%)</th>
<th>INTERPRETATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>95 – 100</td>
<td>Normal</td>
</tr>
<tr>
<td>91 – 94</td>
<td>Mild Hypoxemia</td>
</tr>
<tr>
<td>86 – 90</td>
<td>Moderate Hypoxemia</td>
</tr>
<tr>
<td>&lt; 85</td>
<td>Severe Hypoxemia</td>
</tr>
</tbody>
</table>

Interventions

<table>
<thead>
<tr>
<th>SpO₂ READING (%)</th>
<th>INTERPRETATION</th>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>95 – 100</td>
<td>Normal</td>
<td>Change FiO₂ to maintain saturation.</td>
</tr>
<tr>
<td>91 – 94</td>
<td>Mild Hypoxemia</td>
<td>Increase FiO₂ to increase saturation.</td>
</tr>
<tr>
<td>86 – 90</td>
<td>Moderate Hypoxemia</td>
<td>Increase FiO₂ to increase saturation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Assess and increase ventilation.</td>
</tr>
<tr>
<td>&lt; 85</td>
<td>Severe Hypoxemia</td>
<td>Increase FiO₂ to increase saturation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase ventilation.</td>
</tr>
</tbody>
</table>

Oximetry to Assess Circulation

- Oximeter probe can be placed onto tissue distal to an injury to detect circulation.
- Oximeter can monitor distal circulation with fractures and crush injuries.
- Clinical correlation always needed.
**APPLICATION OF PULSE OXIMETRY**

- Prepare the device:
  - Fresh batteries
  - Wires and probe in good repair.

**Pulse Oximetry**

- Explain the procedure to the patient.
- Apply pulse oximetry probe according to manufacturer's recommendations.
**Pulse Oximetry**

1. Turn on the oximeter.
2. Allow it to proceed through start and self-checks.

**Pulse Oximetry**

1. Check for readings.
2. Check Perfusion Index (PI).
3. Adjust probe, if needed, for best signal.

**Pulse Oximetry**

1. Monitor pulse rate and SpO₂.
2. Adjust oxygen administration to maintain desired SpO₂ levels.
OXYGEN ADMINISTRATION

Oxygen Administration

**Items required:**
- Oxygen source
- Pressure regulator
- Flow meter
- Humidifier (optional)
- Connecting tubing
- Delivery device

**Delivery devices:**
- Oxygen need and patient comfort should drive device selection.
Oxygen Administration

A nasal cannula is comfortable for most patients, yet delivers only a low oxygen concentration.

Oxygen Administration

A non-rebreather mask delivers close to 100% oxygen.

Oxygen Administration

Continuous positive airway pressure (CPAP) is effective in maximizing hemoglobin oxygen saturation. Uses include:
- Congestive heart failure
- Acute pulmonary edema
- Drowning
- CO exposure
Carbon Monoxide

- Carbon monoxide (CO) is the leading cause of poisoning deaths in industrialized countries.
- ~ 3,800 people in the US die annually from CO poisoning.

Carbon Monoxide

- CO results from the incomplete combustion of carbon-based fuels.
- It is odorless, colorless, and tasteless.
- CO is heavier than air and tends to accumulate in the lower aspect of structures.
Carbon Monoxide

- CO detection previously required hospital-based ABGs to measure COHb.
- Technology now available to detect COHb levels in the prehospital and ED setting.

<table>
<thead>
<tr>
<th>Severity</th>
<th>COHb Level</th>
<th>Signs &amp; Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>&lt; 15 - 20%</td>
<td>Headache, nausea, vomiting, dizziness, blurred vision.</td>
</tr>
<tr>
<td>Moderate</td>
<td>21 - 40%</td>
<td>Confusion, syncope, chest pain, dyspnea, weakness, tachycardia, tachypnea, rhabdomyolysis.</td>
</tr>
<tr>
<td>Severe</td>
<td>41 - 59%</td>
<td>Palpitations, dysrhythmias, hypotension, myocardial ischemia, cardiac arrest, respiratory arrest, pulmonary edema, seizures, coma.</td>
</tr>
<tr>
<td>Fatal</td>
<td>&gt; 60%</td>
<td>Death</td>
</tr>
</tbody>
</table>

CO affinity for hemoglobin ~250 times greater than O2.

CO binds 250 times stronger than O2.

CO-Hb has a bright red color. Patients become progressively hypoxemic.

CO displaces O2 from the hemoglobin molecule forming carboxyhemoglobin (COHb).

Cherry red skin color not always present and, when present, is often a late finding. COHb levels do not always correlate with symptoms nor predict sequelae.
Carbon Monoxide

New generation oximeter/CO-oximeter can detect 4 different hemoglobin forms.
Uses 8 different wavelengths of light.
Provides:
- SpO2
- SpCO
- SpMET
- Pulse rate

CO-Oximetry

CO evaluation should be routine at all levels of EMS and the fire service.
All field personnel should be educated in use of the oximeter and CO-oximeter.

Missed CO poisoning is a significant legal risk for EMS and fire service personnel.
COHb Levels in Persons 3-74 Years

<table>
<thead>
<tr>
<th>Smoking Status</th>
<th>% COHb (mean ± σ)</th>
<th>% COHb (98th percentile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsmokers</td>
<td>0.83 ± 0.67</td>
<td>&lt; 2.50</td>
</tr>
<tr>
<td>Current Smokers</td>
<td>4.30 ± 2.55</td>
<td>≤ 10.00</td>
</tr>
<tr>
<td>All persons combined</td>
<td>1.94 ± 2.24</td>
<td>≤ 9.00</td>
</tr>
</tbody>
</table>

CO Treatment

- Treatment is based on the severity of symptoms.
- Treatment generally indicated with SpCO > 12-15%.
- High-concentration O₂ should be administered to displace CO from hemoglobin.
- Be prepared to treat complications (e.g., seizures, cardiac ischemia).

CO Treatment

- Prehospital CPAP can maximally saturate hemoglobin and increase oxygen solubility.
- Strongly suggested for moderate to severe poisonings.
Efficacy of hyperbaric oxygen therapy (HBO) is a matter of conjecture although still commonly practiced. Generally reserved for severe poisonings. May aid in alleviating tissue hypoxia.

CO Treatment Algorithm

CO Poisoning Considerations

Significant and evolving body of literature now suggests that there are numerous long-term and permanent sequelae from CO poisoning.
CO Poisoning Considerations
- Fetal hemoglobin has a much greater affinity for CO than adult hemoglobin.
- Pregnant mothers may exhibit mild to moderate symptoms, yet the fetus may have devastating outcomes.

CO Poisoning
- Remember, CO poisoning is the great imitator.
- Missed CO exposure often leads to death and disability.
- CO is a particular risk for firefighters.

A simple COHb reading can save a life and prevent long-term problems.

CO-Oximetry
- CO-oximetry works the same as pulse oximetry.
- Button brings up SpCO and SpMET (if available) in upper and lower windows respectively.
Parts of cyanide antidote (sodium nitrite) induce methemoglobinemia.

Cyanide antidotes and CO poisoning can lead to elevated COHb and reducing \( O_2 \) capacity of blood.

Hydroxocobalamin is the cyanide antidote of choice for mixed cyanide and CO poisonings.

Sodium nitrite should be avoided for combination cyanide/CO poisonings when SpCO >10%.

Hydroxocobalamin converts cyanide to cyanocobalamin (Vitamin B12) which is renally cleared.

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Credits

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