Oximetry and CO-Oximetry for EMTs and First Responders

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Endorsements

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3

RESPIRATORY GAS PHYSIOLOGY

Respiratory Gasses

- Normal Atmospheric Gasses:
  - Oxygen (O_2)
  - Carbon Dioxide (CO_2)
  - Nitrogen (N_2)
  - Water Vapor (H_2O)
  - Trace gasses:
    - Argon (Ar)
    - Neon (Ne)
    - Helium (He)

Respiratory Gasses

- Most important respiratory gasses:
  - Oxygen (O_2)
  - Carbon Dioxide (CO_2)

Atmospheric Gasses

GAS†	PRESSURE (mm Hg)	PERCENTAGE (%)
Nitrogen (N_2)	593.408	78.08
Oxygen (O_2)	159.220	20.95
Argon (Ar)	7.144	0.94
Carbon Dioxide (CO_2)	0.288	0.03
Neon (Ne)	0.013	0.0018
Helium (He)	0.003	0.0005
TOTAL	760	100

† = dry air at sea level.

Respiratory Gasses

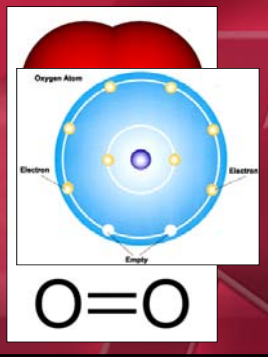
GAS	Atmospheric Air (mm Hg)	%	Humidified Air (mm Hg)	%	Alveolar Air (mm Hg)	%	Expired Air (mm Hg)	%
N_2	597.0	78.6	563.4	74.0	569.0	74.9	566.0	74.5
O_2	159.0	20.8	149.3	19.7	104.0	13.6	120.0	15.7
CO_2	0.3	0.04	0.3	0.04	40.0	5.3	27.0	3.6
H_2O	3.7	0.50	47.0	6.20	47.0	6.2	47.0	6.2
TOTAL	760	100	760	100	760	100	760	100

Oxygen

- Odorless.
- Tasteless.
- Colorless.
- Supports combustion.
- Present in the atmosphere as a diatomic gas (O_2).
- Necessary for animal life.

Oxygen

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

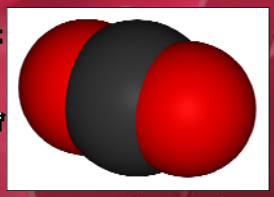


Carbon Dioxide

- 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.

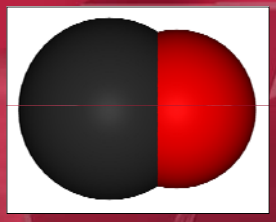


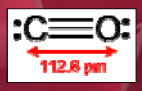
Abnormal Respiratory Gasses

- Carbon monoxide (CO)

Carbon Monoxide

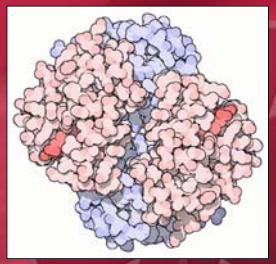
- Colorless
- Odorless
- Tasteless
- Results from incomplete combustion of carbon-containing compounds.
- Heavier than air.



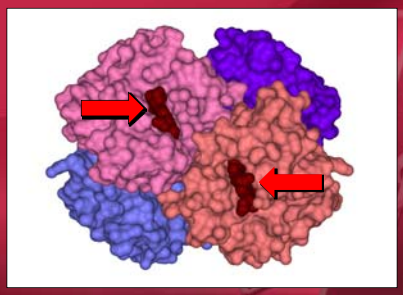


Hemoglobin

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

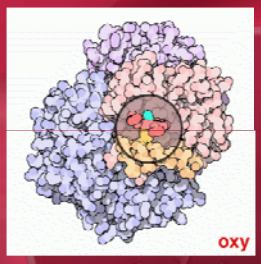


Hemoglobin Binding Sites



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
PO_2	80-100 mm Hg
PCO_2	35-45 mm Hg
HCO_3^-	22-26 mmol/L
BE	-2 - +2
SaO_2	> 95%

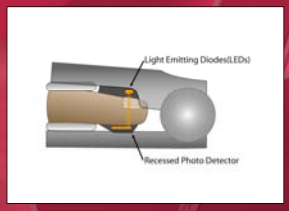
OXYGEN MONITORING

Pulse Oximetry

- Introduced in early 1980s.
- Non-invasive measurement of oxygen saturation.
- Safe
- Inexpensive

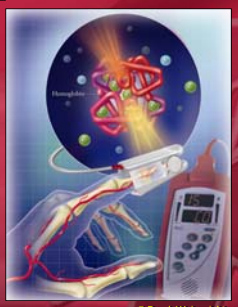
Pulse Oximetry

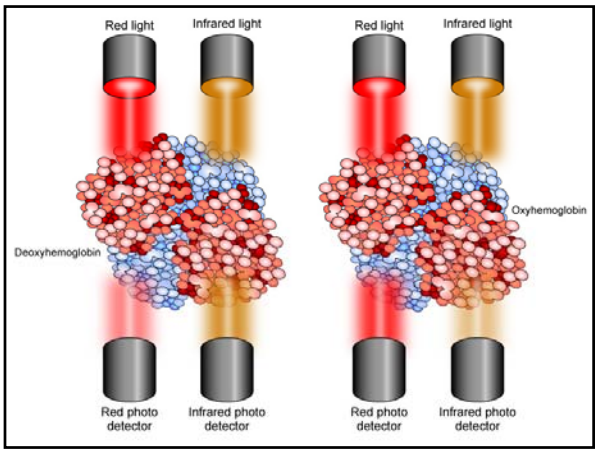
- How it works:
  - Probe is placed over a vascular bed (finger, earlobe).
  - Light-emitting diodes (LEDs) emit light of two different wavelengths:
    - Red = 660 nm
    - Infrared = 940 nm



Pulse Oximetry

- Some light is absorbed by:
  - Arterial blood
  - Venous blood
  - Tissues
- Light that passes through the tissues is detected by a photodetector.

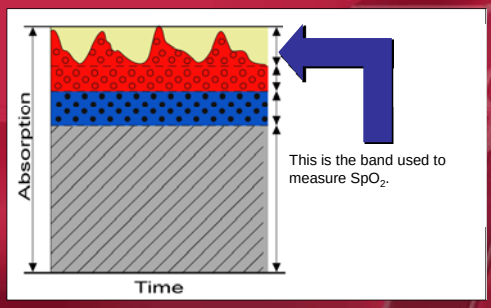




Pulse Oximetry

- Only inflow of blood is used to determine SpO_2.
- Hence the name "Pulse Oximetry"
- Hb and HbO_2 absorb light and different rates due to color and conformation.

Pulsatile Flow



Oximetry Probe Placement

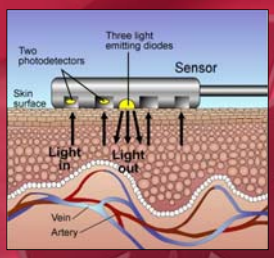
- Finger
- Earlobe
- Heel (neonates)

Oximetry Probe Placement

- 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 the tissues and detected by photodetectors and findings interpreted by the software in the oximeter.
- Can be used on forehead or back.



Pulse Oximetry

- HbO_2 absorbs more infrared light than Hb.
- Hb absorbs more red light than HbO_2.
- Difference in absorption is measured.
- Ratio of absorbance matched with SpO_2 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

SaO_2 or SpO_2?

- SaO_2 used for oxygen saturation readings derived from arterial blood gas analysis.
- SpO_2 used for oxygen saturation readings from pulse oximetry.
- SpO_2 and SaO_2 are normally very close.

Pulse Oximetry

- **Pulse oximetry tells you:**
  - SpO_2
  - Pulse rate
- **Pulse oximetry cannot tell you:**
  - O_2 content of the blood
  - Amount of O_2 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 O_2.**
  - First Responders
  - EMTs
  - EMT-Intermediates
  - Paramedics

Prehospital Indications

1. **Monitor the adequacy of arterial oxyhemoglobin saturation (SpO2)**
2. **To quantify the SpO_2 response to an intervention.**
3. **To detect blood flow in endangered body regions (e.g., extremities)**

Limitations

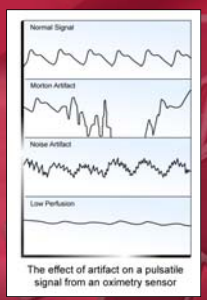
- Oximetry is NOT a measure of ventilation ($EtCO_2$ a better measure of ventilation).
- Oximetry may lag behind hypoxic events.
- Oximetry is not a substitute for physical examination.
- Very low saturation states may be inaccurate due to absence of measured SpO_2 levels in the database.

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

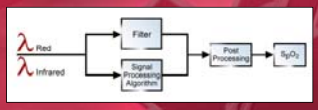
- Motion, noise, and low perfusion states can cause artifacts and false oximetry readings.
- These have been eliminated or minimized in second-generation oximeters.



The effect of artifact on a pulsatile signal from an oximetry sensor

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 SpO_2
- Gender affects SpO_2
- Anemia affects SpO_2
- SpO_2 inaccurate in dark-skinned individuals.
- Jaundice affects SpO_2.

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

What Does it Mean?

SpO_2 READING (%)	INTERPRETATION
95 – 100	Normal
91 – 94	Mild Hypoxemia
86 – 90	Moderate Hypoxemia
< 85	Severe Hypoxemia

Interventions

SpO_2 READING (%)	INTERPRETATION	INTERVENTION
95 – 100	Normal	• Change FiO_2 to maintain saturation.
91 – 94	Mild Hypoxemia	• Increase FiO_2 to increase saturation.
86 – 90	Moderate Hypoxemia	• Increase FiO_2 to increase saturation. • Assess and increase ventilation.
< 85	Severe Hypoxemia	• Increase FiO_2 to increase saturation. • Increase ventilation.

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

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

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

Pulse Oximetry

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

Pulse Oximetry

- Monitor pulse rate and SpO_2.
- Adjust oxygen administration to maintain desired SpO_2 levels.

OXYGEN ADMINISTRATION

Oxygen Administration

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

Oxygen Administration

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

Oxygen Administration

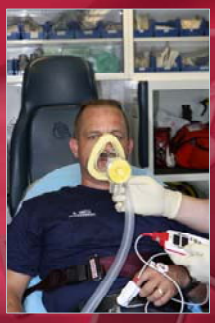
- A nasal cannula is comfortable for most patients, yet delivers only a low oxygen concentration.

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



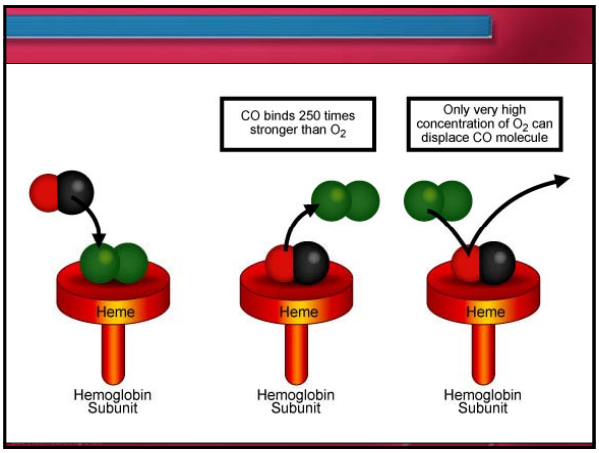
CARBON MONOXIDE AND CO-OXIMETRY

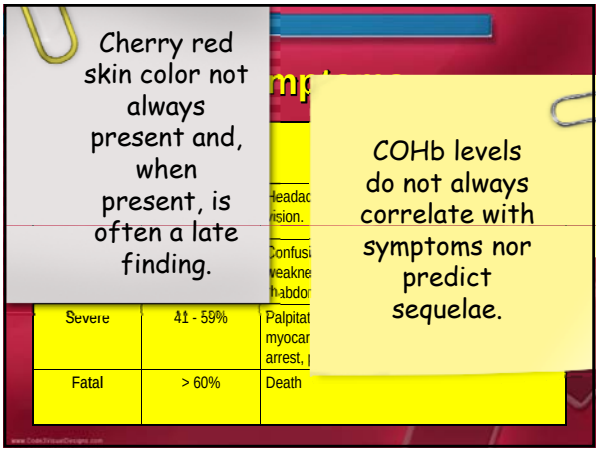
Carbon Monoxide

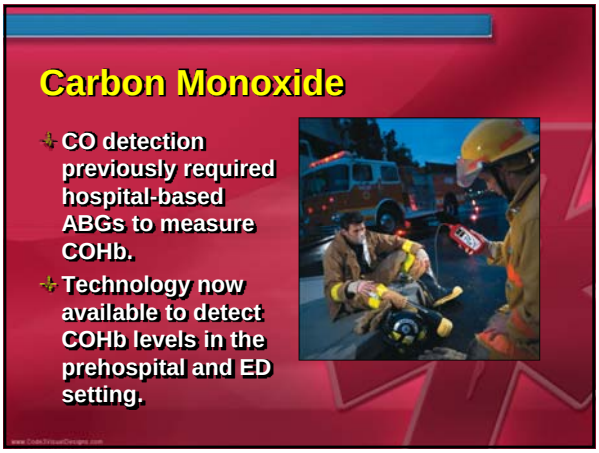
- Carbon monoxide (CO) is the leading cause of poisoning deaths in industrialized countries.
- ~ 3,800 people in the US die annually from CO poisoning.

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.

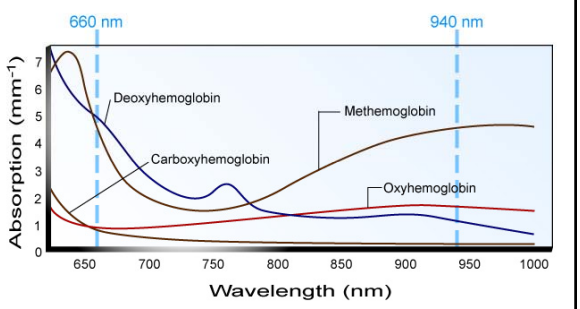

CO binds 250 times stronger than O_2
Only very high concentration of O_2 can displace CO molecule
Heme
Heme
Heme
Hemoglobin Subunit
Hemoglobin Subunit
Hemoglobin Subunit


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.
Severe
41 - 59%
Fatal
> 60%
Death


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.

Carbon Monoxide

- New generation oximeter/CO-oximeter can detect 4 different hemoglobin forms.
- Uses 8 different wavelengths of light.
- Provides:
  - SpO_2
  - 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

Smoking Status	% COHb (mean ± σ)	% COHb (98th percentile)
Nonsmokers	0.83 ± 0.67	< 2.50
Current Smokers	4.30 ± 2.55	≤ 10.00
All persons combined	1.94 ± 2.24	≤ 9.00

CO Treatment

- Treatment is based on the severity of symptoms.
- Treatment generally indicated with SpCO > 12-15%.
- High-concentration O_2 should be administered to displace CO from hemoglobin.
- Be prepared to treat complications (e.g., seizures, cardiac ischemia).

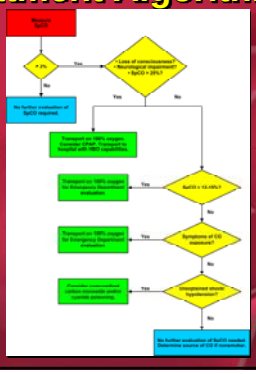
CO Treatment

- Prehospital CPAP can maximally saturate hemoglobin and increase oxygen solubility.
- *Strongly suggested* for moderate to severe poisonings.

CO Treatment

- 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



74

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.

CO and Cyanide

- Parts of cyanide antido
  sodium nitrite) induce
- Cyanide antidotes and
  to elevated COHb and
  reducing O_2 capacity o
- Sodium nitrite should
  combination cyanide/C
  SpCO >10%.
- Hydroxocobalamin co
  cyanocobalamin (Vitam
  cleared.

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

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82