CARBON MONOXIDE AND CYANIDE POISONING

KENT HOSPITAL

Gases

OXYGEN = O_2 → Supports Life

CARBON DIOXIDE = CO_2 → Product of Life

CARBON MONOXIDE = CO → Destroys Life!

CO MEASUREMENT

- **Mechanics:** measured in blood & expired air
- **Gold Standard:** carboxyhemoglobin (COHb)
- **COHb Level:** inconsistent with degree of toxicity

COHb BLOOD STABILITY

recently questioned due to a study showing a significant and progressive decline in COHb blood samples in closed tubes.

CARBON MONOXIDE TOXICITY

- **Scope of the Problem:** > 40,000 annually in US; 0.5 – 1.0 / 1,000,000 people fatality rates may be responsible for 50% of all fatal poisonings
- **CO Toxicity:** MCC of death in fire victims
- **Affinity:** combines with Hg 220 X than O2
- **Only Adequate Treatment:** removal & HBO
- **Relapses:** common unless HBO is repeated
- **Poor Record:** 5% - 6% ED patients receive HBO

Speeds COHb Dissociation

Room Air: CO ½ life – 320 min
100% O2: CO ½ life - 90 min
HBO (3 ATA): CO ½ life - 23 min

Most important event in CO pathophysiology is Hb binding

CARBON MONOXIDE POISONINGS

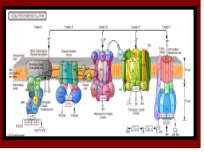
- **New Recognition:** more complex than previously recognized
- **Intoxication by 3 Mechanisms:**

PURE CO POISONING
water heaters supplied by methane, butane or propane yield only CO, CO2 & H2O

SMOKE INHALATION
O2, CO, CO2, CN & Irritant Gases

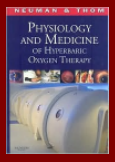
AUTO EXHAUSTS
CO2, CO, NO & Organic Volatiles

MECHANISM OF CO POISONING
Binds Cytochrome C Oxidase - inhibits mitochondrial respiration



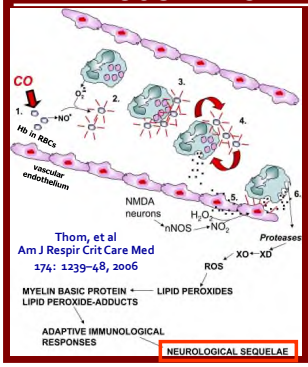
VARIABLES IN CO UPTAKE / ELIMINATION

- [CO] in breathing gas & relation to other partial pressures
- Density, Temperature & Humidity of Gas Mixture
- Alveolar Ventilation
- CO Alveolar - Pulmonary Gradient
- Cardiac Output
- Pulmonary CO Diffusing Capacity
- Speed of Reaction of CO with Hemoglobin
- Quantity & Speed of Lung Capillary Blood Flow
- Hemoglobin & Hematocrit Values
- Rate of Endogenous CO Production / Consumption
- Rate of CO Elimination



Neuman & Thom – Physiology & Medicine of Hyperbaric Oxygen Therapy

PERIVASCULAR OXIDATIVE CHANGES



Thom, et al
Am J Respir Crit Care Med
174: 1239–48, 2006

1. CO competes with nitric oxide (•NO) for binding sites & ↑ [•NO]
2. •NO interacts with superoxide anions (O2-) made by neutrophils to produce peroxynitrite (ONOO-) which activates platelet adhesion molecules
3. This leads to platelet-neutrophil aggregates
4. An oxidative burst then occurs & additional reactive •NO derived species are made which degranulates more neutrophils
5. Neutrophils adhere to vascular lining & the vicious cycle repeats

CO POISONING CNS TOXICITY

COHb Level does NOT correlate with the Development of Neurological or Cognitive Sequelae

- Permanent Brain Damage: 14% of survivors
- Delayed Neurological Sequelae (DNS): 3 - 21 days (21%)

EFFECT ON HIGHER BRAIN FUNCTIONS

- Dysfunctions: memory, perception, attention and concentration
- Decline in: new learning ability, tracking skills, visual-motor skills, abstract thinking & visual–spatial planning
- Other Abnormalities: personality changes and a Parkinsonian-Like Syndrome - occurs 2 weeks later with bradykinesia but without a tremor

CO POISONING CNS TOXICITY

NEUROPSYCHOMETRIC TESTING
sensitive in detecting subtle dysfunctions

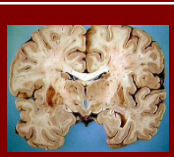
PHYSICAL EFFECTS
Incontinence - Gait Disturbance – Tremor
Speech Impairment - Frontal Lobe & Cerebellar Signs

"LATE SYNDROME" (2 – 3 weeks post-insult)
Oligodendrocyte loss 2° white matter myelin loss.
Ammon's Horn destroyed (short term memory)

NEUROLOGICAL SEQUELAE
10% - 20% without HBO; 0% - 4% with HBO

CO POISONING NEUROPATHOLOGY

- Basal Ganglia Lesions: 70%
- Gray Matter Lesions: 30%
- White Matter Lesions: 30%
- Spongy Leukoencephalopathy
- Symmetric Myelinopathy: deep central white matter and periventricular zones
- Cerebral Edema
- Cell Death: necrosis & apoptosis



globus pallidus & putamen

CO patients lacking the apolipoprotein e4 allele have ↓ cognitive sequelae if treated with HBO

CO POISONING TREATMENT

- 100% Oxygen: tight-fitting mask or ETT
- Labs: COHb, Lactate, CXR, EKG, drug screen, ABG
- Awake Pts: use lactate & neuropsychometric tests to determine condition & guide treatment
- Lactate & CK Levels: check serially in the CSF
  - Comatose Pts: lactate predicts outcome
  - If Victims Don't Waken Quickly: use CSF rather than serum levels for prognostication

Supplemental Oxygen is the Cornerstone of Treatment
However no Trials Demonstrate Improved Outcomes

CRITERIA FOR HBOT

Anginal Pain or Ischemic Changes on EKG
Measurable Neurologic Impairment
Any Unconsciousness, Transient or Prolonged

Heart Disease
Renal Dysfunction
> 60 years old
Severe Metabolic Acidosis
Pregnant (> 15% COHb)
COHb > 25%
Persistent Symptoms

↑COGNITIVE SEQUELAE
Age > 36 years
CO Exposure > 24 hrs
Pre-Existing
Cerebellar Dysfunction

Cardiac Arrest Predicts a Dismal Outcome
with or without HBOT

PREGNANT CO PATIENTS & HBOT

MATERNAL SYMPTOMS
during exposure are more predictive than COHb levels

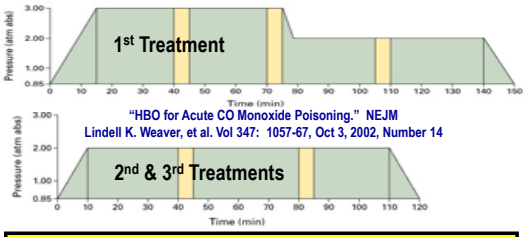
SEVERE CO POISONING
Mom Mortality = 19% - 24%
Fetal Mortality = 36% - 67%

FETAL MORBIDITIES
Malformed Limbs
Hypotonia / Areflexia
Persistent Seizures
Microcephaly
Mental & Motor Disabilities

CO POISONING LAB STUDIES

- COHb: heparinized blood tube (art or ven) at beginning of O2 therapy for later analysis (CO elimination curve)
- Psychometric Tests: more sensitive indicator of exposure
- Lab Abnormalities: ↑ CPK, MB, troponin, BUN, & Cr
- Serum Lactate: may be only abnormal lab finding after a period of surface O2
- Myoglobinuria: significant rhabdomyolysis
- EEG: non-specific diffuse changes (encephalopathy)

HBO CHAMBER SESSIONS



"HBO for Acute CO Monoxide Poisoning." NEJM
Lindell K. Weaver, et al. Vol 347: 1057-67, Oct 3, 2002, Number 14

AHA LEVEL OF EVIDENCE = A
Persistent Neuro Sxs (< 6 hrs) = q d or BID until plateau
Utilization Review = after 5th treatment
Benefit of HBO > 6 hrs = unknown
HBO use in Smoke Inhalation = not enough evidence

HBO BOARD QUESTION

A 50 y/o man presents to the ED with carbon monoxide poisoning. Which of the following chemicals in his garage is the most likely to lead to carbon monoxide poisoning?

A. Acetone
B. Methylene Chloride
C. Methylene Blue
D. Isopropyl Alcohol
E. Wood Glue

Methylene Chloride, a paint stripper, is a relatively common source of CO poisoning

HBOT TREATMENT PROTOCOL

- 100% O2: at 3.0 ATA for minimally 30 minutes, followed by treatment at 1.9 to 2.5 for 90 min – 3 hrs
- Thom: lipid peroxidation blocked by HBO at 3 ATA (only moderate effect at 2 ATA); same for inhibition of leukocyte adherence
- Table Treatment 6: has been used with success
- Repeat Treatments: Gorman found that at one year f/u, pts who received 2 HBO treatments were better off than those who received just one.

TREAT AGGRESSIVELY
a single treatment is frequently not enough

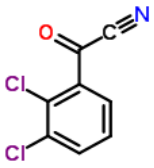
BENEFITS OF HBOT

- Reduces Cerebral Edema & ICP: vasoconstriction
- Halts Ischemic-Reperfusion Injury: by inhibiting leukocyte B2 integrins & decreasing leukostasis (benefit unmatched by other txs - ↓ neuro sequelae)
- Prevents Brain Lipid Peroxidation: animal studies
- Restores (Mitochondrial) Cytochrome Redox State, pH & Energy: surface O2 may result in energy failure & cellular acidosis despite eliminating CO
- Maintains Tissue Oxygenation & Dissociates CoHb
- Animal & Human Studies: show a ↓ mortality, ↓ neurological sequelae + ↑ cardiovascular status

CO VERSUS CYANIDE TOXICITY

You are evaluating a fire victim. Your intern reports a lactate level of 10 mmol / L.

Severe lactic acidosis occurs in severe CO cases. However cyanide levels were not documented. Pure CO toxicity may ↑ plasma lactate, however there is a poor / no correlation between lactate levels & COHb levels unless a sustained exposure or LOC. There is a strong positive correlation between blood cyanide & and either an anion gap or elevated plasma lactate.



CO VERSUS CYANIDE TOXICITY

EMS transports a fire victim, GCS 3, intubated with soot at nares & mouth.

Transitory LOC is consistently reported in pure CO poisonings with improvement upon removal & O2. Intubation is rarely required. With cyanide, LOC is sustained & requires intubation.

CO VERSUS CYANIDE TOXICITY

EMS presents with a presumed gas exposure patient. No obvious trauma, but comatose with dilated pupils.

Dilated pupils often seen with cyanide-induced coma but rare in CO victims (at presentation).

CO VERSUS CYANIDE TOXICITY

EMS reports fire victim, initially tachycardic & hypertensive, but then became hypotensive, and is now bradycardic.

This is the presentation for cyanide toxicity. The bradycardia immediately precedes cardiac arrest. Hypotension is the hallmark of significant cyanide poisoning. There is a decrease in SBP in CO poisonings with a low incidence. Bradycardia is rare in pure CO poisonings.

CO VERSUS CYANIDE TOXICITY

Bystanders report a fire victim seizing at the scene, no obvious trauma.

Seizures are listed as common in CO, however a prospective study showed a 2.9% incidence. Convulsions common with cyanide poisonings.

TRIVIA BONUS

- IN WHAT FOODS DOES CYANIDE NATURALLY OCCUR?

CO VERSUS CYANIDE TOXICITY

Fire victim with nausea, vomiting, dizziness, and a headache. The symptoms remain stable with removal from source and supplemental oxygenation.

This is Mild Cyanide Poisoning if there are no further Cardiovascular or Neurological Symptoms

OTHER CYANIDE ANTIDOTES

- 4-Dimethylaminophenol
- Dicolbalt Edetate (Kelocyanor)
- Stroma-Free Methemoglobin
- Alpha-Ketoglutarate
- Dihydroxyacetone
- Nitric Oxide
- Hemodialysis
- Hyperbaric Oxygen Therapy