

# Carbon Monoxide Poisoning

Lindell Weaver, MD  
 Hyperbaric Medicine, LDS Hospital &  
 Intermountain Medical Center  
 Professor, University of Utah  
 Salt Lake City, Utah  
 Adjunct Professor, Department of Anesthesia, Duke  
 University, Durham, NC

•1

# Carbon monoxide (CO)

- Colorless, Odorless, Bi-product of combustion
- High affinity for Hb
- 50,000 Emergency Department visits each year in the USA<sup>1</sup>
- Deaths: 1,967 (1999); 1,319 (2014)<sup>2</sup>
- FREQUENTLY UNRECOGNIZED

<sup>1</sup>Hampson UHM 2007; 34(3):163-8

<sup>2</sup>Hampson ATS Journal 2016

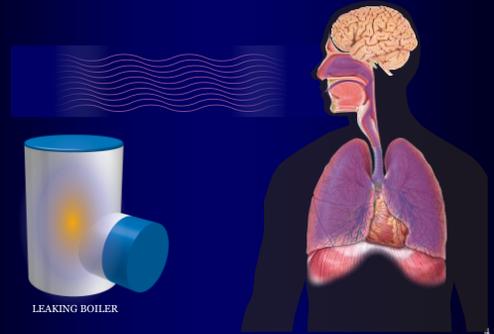
•2

# CO - Pathophysiology

- **Hypoxia**
  - COHb, Left-shift of HbO<sub>2</sub> curve, cytotoxicity (aa3), CO-myoglobin and CO-P450
- **Oxidative stress**
  - ↑ Excitatory Amino Acids
  - Lipid peroxidation (ischemia/reperfusion)
  - Endothelial peroxynitrate → vascular damage
- **Inflammation**
  - Myelin basic protein → inflammation
  - Fe<sub>2+</sub> release
- **Apoptosis**

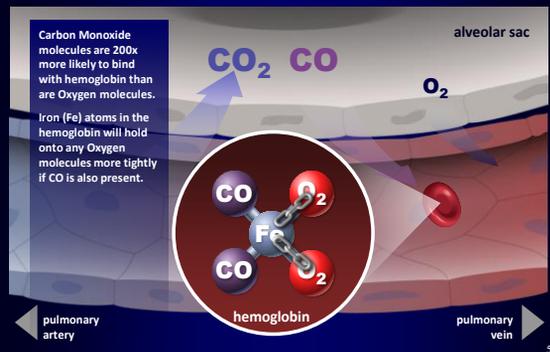
•3

# Carbon Monoxide Poisoning



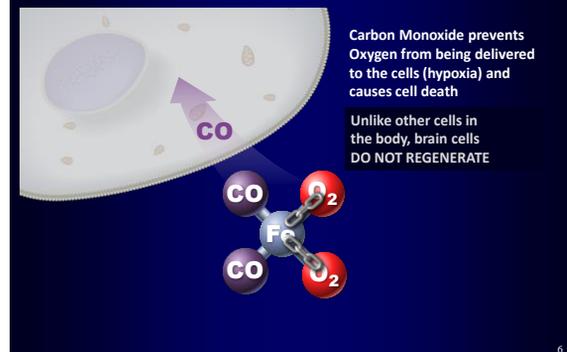
•4

# Hypoxia and Cell Death



•5

# Hypoxia and Cell Death



•6

### Carbon Monoxide Halts the Production of ATP – an Essential Molecule for Life

Adenosine triphosphate (ATP) is considered by biologists to be the energy currency of life and is essential for all physiological mechanisms that require energy to operate

mitochondria produces ATP

7

•7

### Oxidants and Antioxidants

Antioxidants

mitochondrion

A result of Carbon Monoxide's interaction, MORE oxidants are produced than the anti-oxidants can counteract

8

•8

### Immune System Neutrophils and Inflammation

When Carbon Monoxide is present, neutrophils release a burst of oxidants prematurely and attack healthy cells, triggering an immune response of inflammatory cells

neutrophil part of the immune system

9

•9

### Lipid Destruction

lipid bi-layer

lipid peroxidation products

10

•10

### Neuron Damage

Neuron

Myelin Sheath

Axon

lipid peroxidation products

11

•11

### Neuron Damage

Neuron

Myelin Sheath

Axon

lipid peroxidation products

Immune Cells attack neuron causing cell death

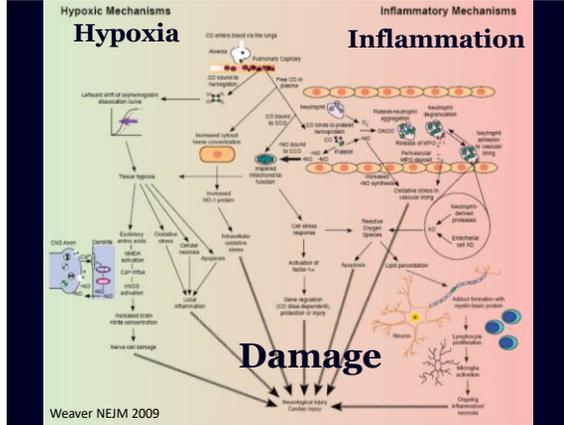
12

•12

## CSF after CO poisoning

- In those with problems, myelin basic protein elevated weeks after poisoning
- Preliminary, but serotonin metabolites reduced in several more than 1 year after poisoning

•13



•14

## CO and Microparticles

- Mice exposed to CO at 100 ppm x 1 hour showed circulating microparticles from various vascular cells, and neutrophil activation.
- Microparticles generated by decompression stresses precipitate neutrophil activation and vascular damage

Thom J Appl Physiol 2011  
Thom Toxicol Appl Pharm 2013

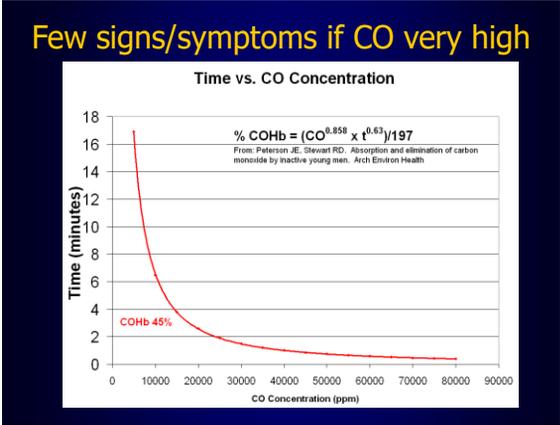
•15

## CO Poisoning Plasma Biomarkers

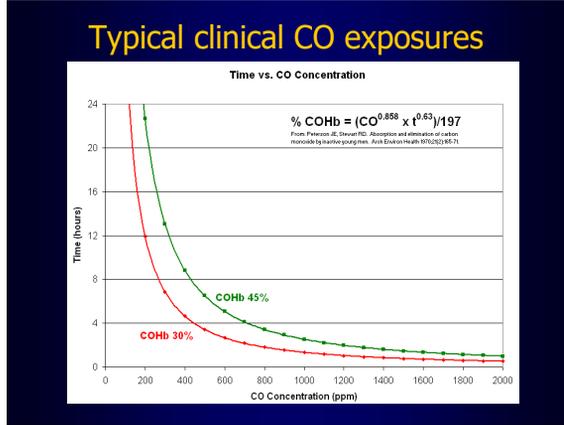
- 63 acutely CO poisoning patients (severe to mildly poisoned)
- 42-matched controls
- 180 proteins assayed
- Acute Inflammation present: Complex elevations: acute phase proteins, chemokines, cytokines, interleukins, growth factors, hormones, auto-antibodies
- For many measures, poisoning severity not linked to abnormal measures.

Thom, et al., Clin Toxicol 2010

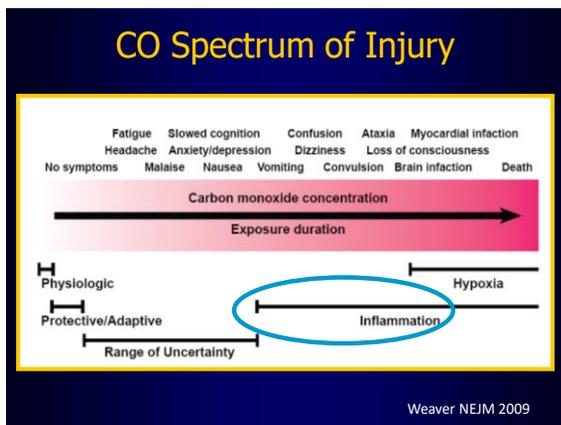
•16



•17



•18



•19

### Case with interview

- 24 year old cutting concrete in his basement for 75 minutes, syncope x 3
- COHb = 17.5% after 60 min O2
- At 6 weeks: abnormal Sharpened Romberg and UE distal weakness
- At 6 month: Heel-toe gait, Romberg, Sharpened Romberg, pronator drift, left-sided weakness, nystagmus, lack of smooth pursuit

•20

### CO case, interview summary

- Forgetfulness, including destination
- Uneasy
- Reduced work productivity/efficiency
- Eye twitching and reduced focus
- Energy decreased; tired
- Hearing perception problems
- Balance reduced

•21

### CO poisoning - Sequelae

- Cognitive
- Depression/Anxiety/Psychosis/Sleep/PTSD
- Motor (including Parkinson's)
- Neuropathy
- Coordination
- Vestibular (n=64: ½ vestibular; 1/3 balance abnormalities; UHMS 2008)
- Visual disturbances (1/3 abnormal, UHMS 2014)
- EEG (1/3 abnormal, UHMS 2014)
- Hearing loss

•22

### CO – Long-term outcome

63 followed to 3 years

- 21 (33%) deterioration in personality
- 27 (43%) deterioration in memory

Smith and Brandon. BMJ 1973

•23

### CO – Really long-term outcome

- 50 patients from our RCT or prior prospective one-year outcome studies followed from 3.5-10.2 years after poisoning (mean time from poisoning = 6 years):
  - 25% with neuropsychological sequelae
  - 38% with neurological abnormalities

•24

## CO – Really long-term outcome

- N=156; Mine disaster 33 yrs prior, mean age 69.2 yrs
- Coma: 0-6 hr (64); 6-12 hr (46); 12-48 hr (46)
- **Symptoms in 97%** (Forgetful 90%, Irritability 67%, Headache 60%, Insomnia 56%, Limb pain 47%, Dull head 43%, Dizziness 36%)
- **Intellectual disturbances in 58%**
- **Apathy 72%; Personality change 54%**
- **Neurologic 49%**: sensory 26%, peripheral nerve 16%, pyramidal 14%, ataxia and CN 7%, focal 4.5%, extrapyramidal 22% (Parkinsons 4%, tremor 11%, rigidity 16%)
- **MRI** – atrophy 72%, pallidum 38%, lacunar 53%, hippocampal atrophy 19%

Mimura K, Seishin Shinkeigaku Zasshi. 1999 (Japanese); soon in English in UHMI

•25

## Increased mortality after CO poisoning

- n=1,073, 1978-2005; all Tx with HBO2
- 11,741 person-years – 162 died; expected = 87 (mortality ratio = 1.9; CI: 1.6-2.2)
- Suicide: increased death later
- **Accidental: increased death later too – cognitive impairment leading to unintentional injury**
- No increased CV mortality

Hampson CritCareMed 2009

•26

## CO Poisoning and HBO<sub>2</sub> Less severe v. more severe at presentation

- No difference in 6-week cognitive sequelae between patients with less severe v. more severe poisoning.
- It is not clear that the patient’s presentation details can predict subsequent outcome.
- Therefore, **HBO<sub>2</sub> for patients with CO poisoning.**

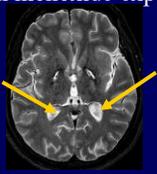
Brain Injury 2008

•27

## Quote from a recent MRI Report

History of prior Carbon Monoxide Exposure

“No globus pallidus abnormal signal to indicate brain injury from prior carbon monoxide exposure.”



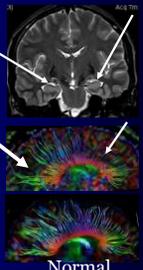
Often absence of abnormal signal in the globus pallidus is assumed to mean no brain injury from carbon monoxide.

**WRONG!!**

•28

## Brain imaging abnormalities in CO-poisoned patients with ongoing symptoms at least 6 months after poisoning

- Hippocampal atrophy: 118 (73%)
- Dilated perivascular spaces: 84 (52%)
- White matter hyperintensities: 73 (45%)
- Decreased fiber tracks across corpus callosum on DTI: 99/134 (74%)
- Abnormal:
  - fMRI: 56/96 (58%)
  - Multi-voxel MR spect: 30/83 (36%)
  - Perfusion on CT: 22/41 (54%)
- Basal Ganglia MR Spectroscopy: ??



Normal

Weaver, Orrison, Deru, McIntosh, UHM 2015

•29

## Medical Work-Up of Carbon Monoxide Poisoned Patient

- Vestibular testing
- Speech
- Psychiatry
- Cardiac
- Lung function
- Neuropsychiatry
- Neurology
- EEG
- Imaging studies (brain and heart)
- Labs
- Sleep studies

Some patients need brain injury management: Voc rehabilitation, Functional Capacity Evaluation, Disability Impairment, Disability (SSI, etc.)

•30

### CO sequelae mimicks post-concussive symptoms

- False sense that since the injury cannot be seen, recovery should be **quick and easy**.
  - Old research suggesting recovery in term of weeks rather than the months that are required, but **recovery often incomplete** (22% with problems at one year in the TRACK study)
  - REALITY that some individuals will live with consequences **PERMANENTLY**
- Struggle with the same spectrum of difficulties especially related to **fatigue, affective functioning and executive functioning**
- **Similar risk to future functioning difficulties**

•31

### CO sequelae mimicks post-concussive symptoms

- In mild TBI with persistent symptoms, **patient reports are the best outcome**.
- There is no accepted composite outcome or biomarker.
- Best assessment tools:
  - Neurobehavioral Symptom Inventory
  - Rivermead Post Concussion Questionnaire
  - Mayo-Portland Adaptability Inventory

•32

### Management of Sequelae

- Patients should be informed that they may not fully recover after CO poisoning
- Cardiac stress evaluations
- Psychotherapy
- Brain injury support groups
- Education regarding prevention -[www.cdc.gov/co/](http://www.cdc.gov/co/)
  - Ask about whether they have a CO alarm
- Neuropsychiatric sequelae that do not resolve should be treated, preferably by a specialist
  - Suicide attempt survivors should be treated immediately and aggressively

•33

### CO poisoning – Hotels, Motels, 2007

- 1989 – 2004; online, legal search
- 68 incidents: 772 poisoned, 711 guests, 41 employees/owners, 20 rescue personnel
- 27 died, 66 confirmed sequelae,
- 6 jury verdict.
- Public verdicts averaged \$4.8 M (\$1 – \$17.5)

Am J Prev Med 2007;33:1-5

•34

### CO poisoning – Hotels, Motels, 2019

- 2005 to 2018. online searches and professional experience of the authors.
- 905 guests were poisoned in 115 identified incidents,
- 22 fatalities
- Children represented 16% of those poisoned and 27% of fatalities.
- Hotels, motels, and resorts of all classes and located in a majority of states.
- Most poisonings could have been prevented by an in-room carbon monoxide alarm.
- Government should mandate installation of in-room CO alarms, similar to the current requirement for smoke alarms.

Prev Med Reports 2019; 16

•35

### CO Prevention - Alarms





\$40.00/5-7 years

\$240.00, Internet  
([www.coexpert.com](http://www.coexpert.com))  
10 years, on/off switch,  
Low level, rapid response

•36

## CO Alarm Response Times

Ambient CO Concentration (ppm)	Alarm Response Time (minutes)
70	60-240
150	10-50
400	4-15

Alarms should be replaced every 5 years  
(3 years if low humidity)

Courtesy: LK Weaver

•37

### Cats saves family from CO

**'LUCKY' TO BE ALIVE!**

Howling cat SAVES FAMILY from carbon monoxide poisoning

Tara and Joe have decided to keep Lucky in the family. Below, their baby Austin.

"We didn't realize what she was trying to tell us," recalls 27-year-old Tara. "It was the most awful noise you've ever heard."

Knowing the only thing that does differently was from the house, Tara immediately grew concerned about her family.

"We were both sleeping in the living, we couldn't take any chances," she says. "We turned off the heat and opened a door and a window to let the wind blow in. Three minutes later, Lucky stopped howling and went to sleep."

**TWO DAYS LATER, TARA NOTICED THAT HER** baby, Austin, started sick. She rushed to the furnace for the second time.

Again, Lucky started acting up almost immediately.

The time, Tara knew there had to be a major problem with the furnace. Joe, a 30-year-old welder, called the gas company, and a technician arrived.

"The gas is machine in our vents and the carbon monoxide levels kept going up," says Tara. "We switched heat exchanger and had to finally call the records into the house through all the vents."

Lucky the cat had saved the family.

"I'm so grateful to be alive," says Tara. "We might have had our entire family that night. We might have gone to sleep and never woken up again."

With a new baby on the way, Tara says they had considered finding a new home for Lucky.

"We have Austin now," she has a home for the rest of her life."

By JAMES BRIDGEMAN  
jbr@thejournalstar.com

NEA 28 November 6, 2010

Every three five days burned on their furnace. Lucky got sick a horrible accident.

Courtesy: LK Weaver

•38

## CO poisoning – prevention!

- CO poisoning causes damage
- Treatment effectiveness is incomplete
- Simple prevention strategies can prevent most accidental poisoning (CO alarms, furnace inspections, no operation of motors indoors, no charcoal cooking or heating indoors)

•39