

A photograph of a medical team in a hospital setting. On the left, an older man with grey hair and glasses, wearing a white lab coat, is looking down at a patient. Next to him, a younger man in blue scrubs and glasses is also looking down. To the right, a woman in blue scrubs is looking at a tablet. Further right, a man in blue scrubs is looking at the tablet. On the far right, a woman in blue scrubs is looking at the tablet. They are all wearing blue gloves. The patient is lying on a gurney, covered with a white sheet. In the background, there are medical monitors and equipment.

Smoke Inhalation

Craig Smollin MD

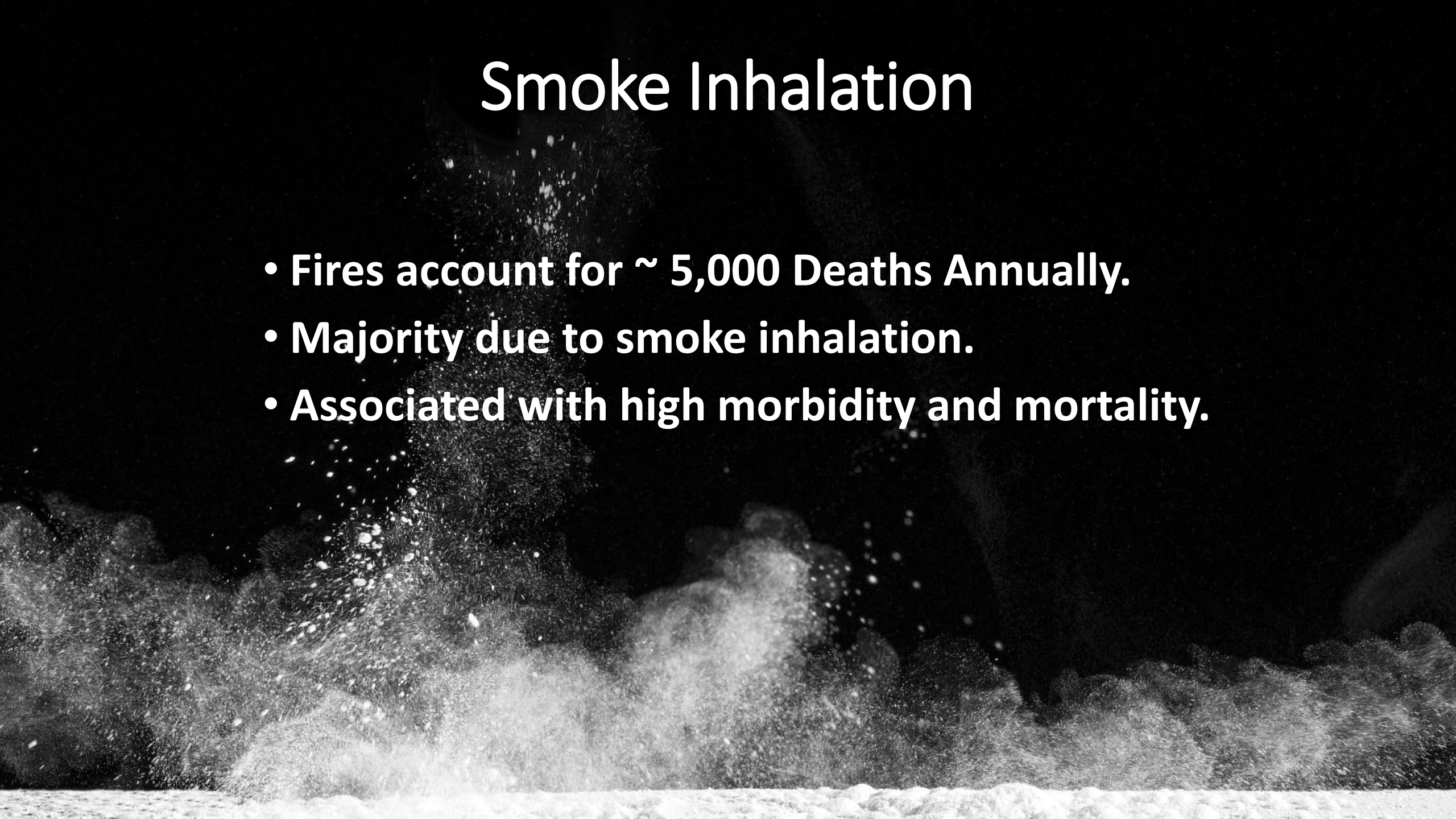
Professor of Clinical Emergency Medicine, UCSF
Medical Director, California Poison Control System- SF Division

Disclosures

- I have no financial relationship to any of the commercial products discussed in this talk.

Smoke Inhalation

- Fires account for ~ 5,000 Deaths Annually.
- Majority due to smoke inhalation.
- Associated with high morbidity and mortality.



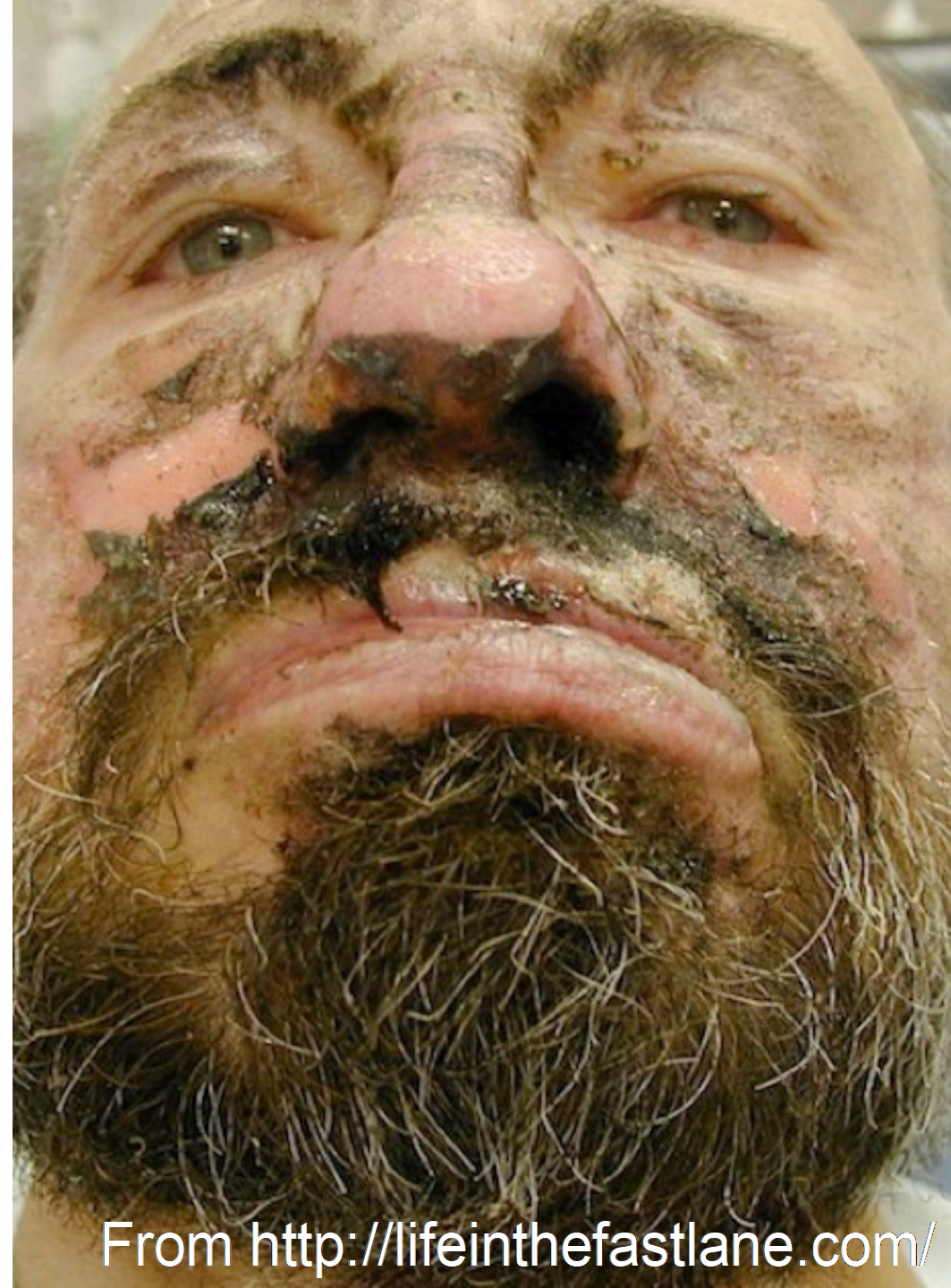
The Station Night Club Fire, Feb 20, 2003



100 killed, 230 Injured

Case #1

- A 40-year-old male is pulled from an enclosed fire.
- Confused and agitated
- Coughing up soot and complaining of difficulty breathing.
- BP 90/60, HR 120, RR 30, O2 sat 95% on RA



From <http://lifeinthefastlane.com/>

What Injuries to Expect?

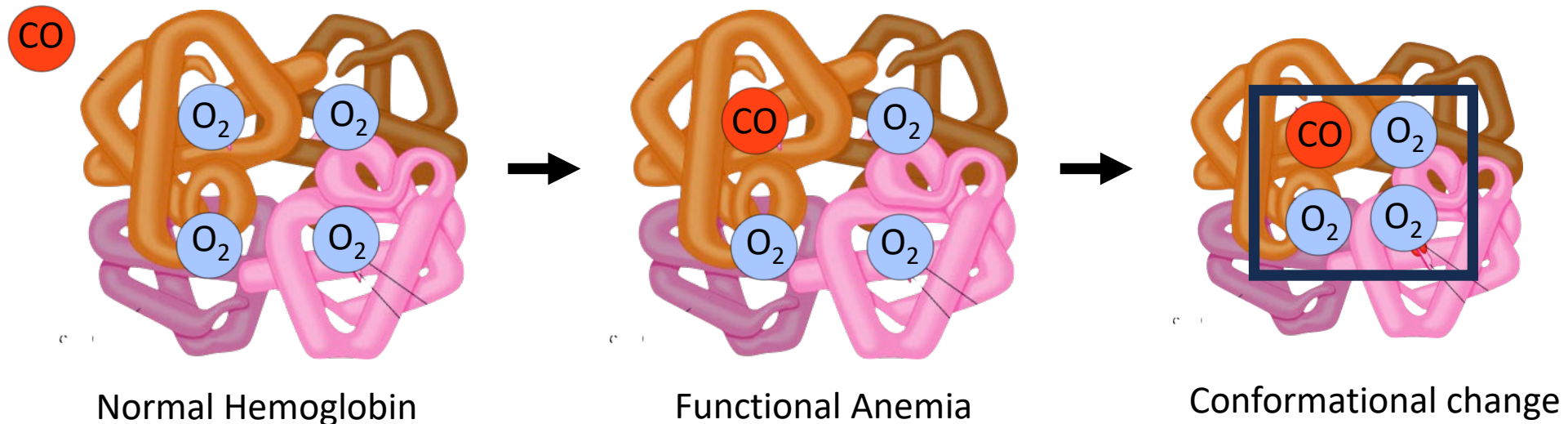
- Thermal burns to the upper airway
- Chemical injury to the upper airway (Ammonia, sulfur dioxide)
- Chemical injury to the lower airway
- **Systemic effects of absorbed toxins in smoke**

Objective for this talk

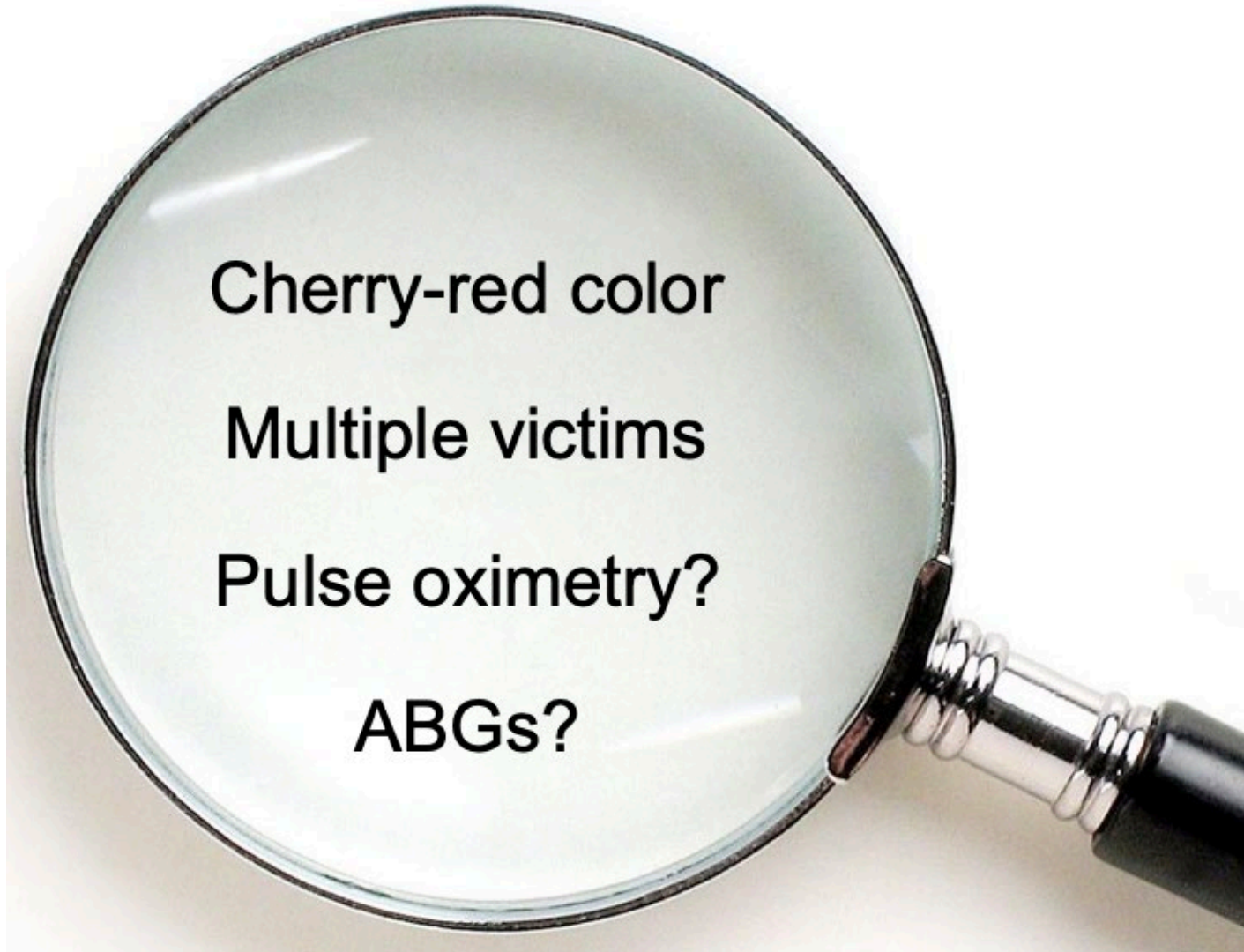
- Focus on the systemic toxicity of inhaled toxic gases:
 - Carbon Monoxide
 - Cyanide
- Explore some common clinical questions:
 - Utility of noninvasive carboxyhemoglobin measurements
 - Efficacy of hyperbaric oxygen therapy
 - Utility of cardiac testing in patients with CO exposure

CO Pathophysiology

- Binds to hemoglobin with higher affinity than oxygen (250:1)
- Functional anemia
- Changes hemoglobin such that it won't release oxygen (left shift)



Carbon Monoxide: Clues to the Diagnosis



Cherry-red color

Multiple victims

Pulse oximetry?

ABGs?

Cherry Red Skin is a Post-Mortem Finding



<https://webpath.med.utah.edu/FORHTML/FOR126.html>

ABG pO₂ Will be Normal in CO Poisoning



Standard Pulse Oximetry in CO Poisoning is Unreliable



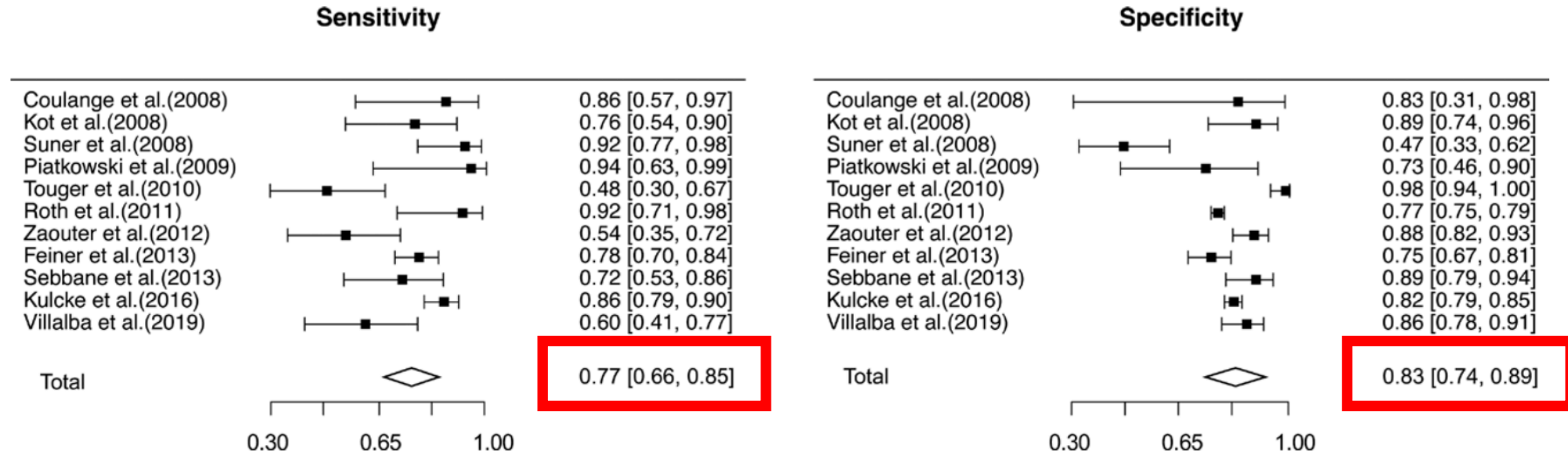
What About Non-invasive Pulse Co-oximetry (SpCO)?



Accuracy of pulse CO-oximetry to evaluate blood carboxyhemoglobin level: a systematic review and meta-analysis of diagnostic test accuracy studies

Mathilde Papin^a, Chloé Latour^b, Brice Leclère^{c,d} and François Javaudin^{a,d}

Fig. 2



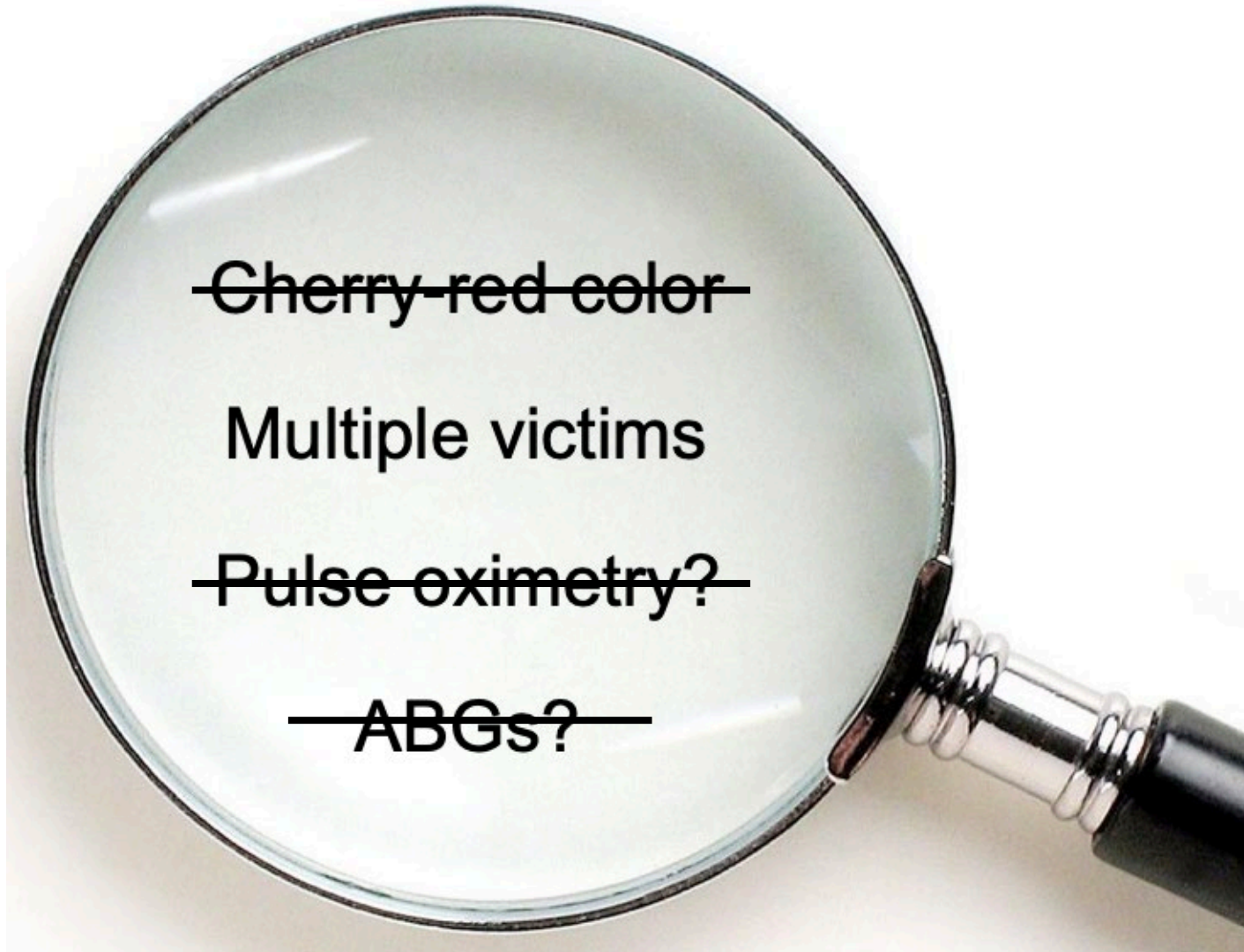
Sensitivities and specificities of the 11 included studies.

Conclusion: Non-invasive SpCO not highly accurate.



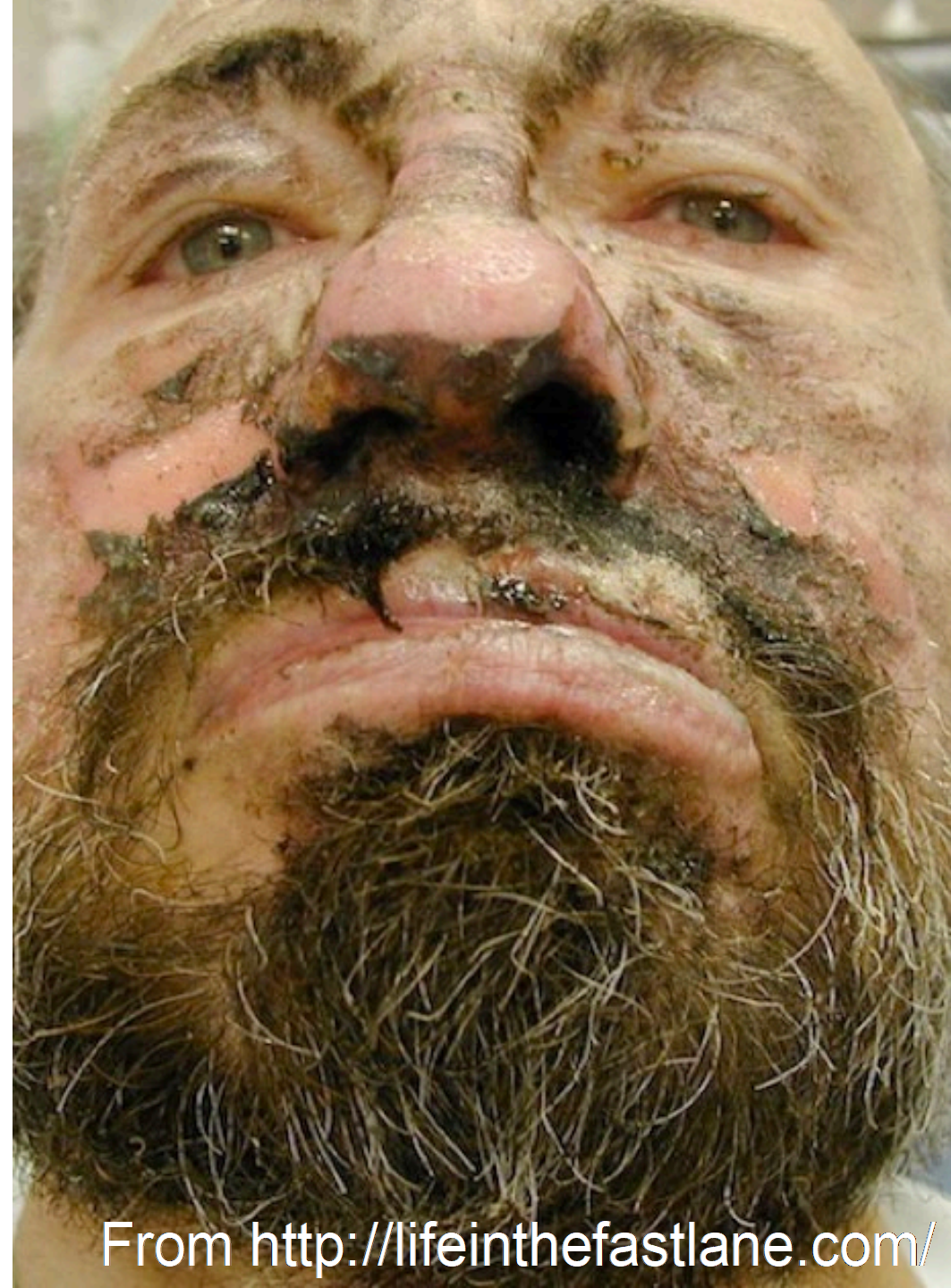
- Clinical Policy: Critical Issues in the Evaluation and Management of Adult Patients Presenting to the Emergency department With Acute Carbon Monoxide Poisoning (2016)
- Can Noninvasive COHb measurements be used to accurately diagnose CO toxicity?
- **Level B Recommendation: Do not use.**

Carbon Monoxide: Clues to the Diagnosis



Case #1

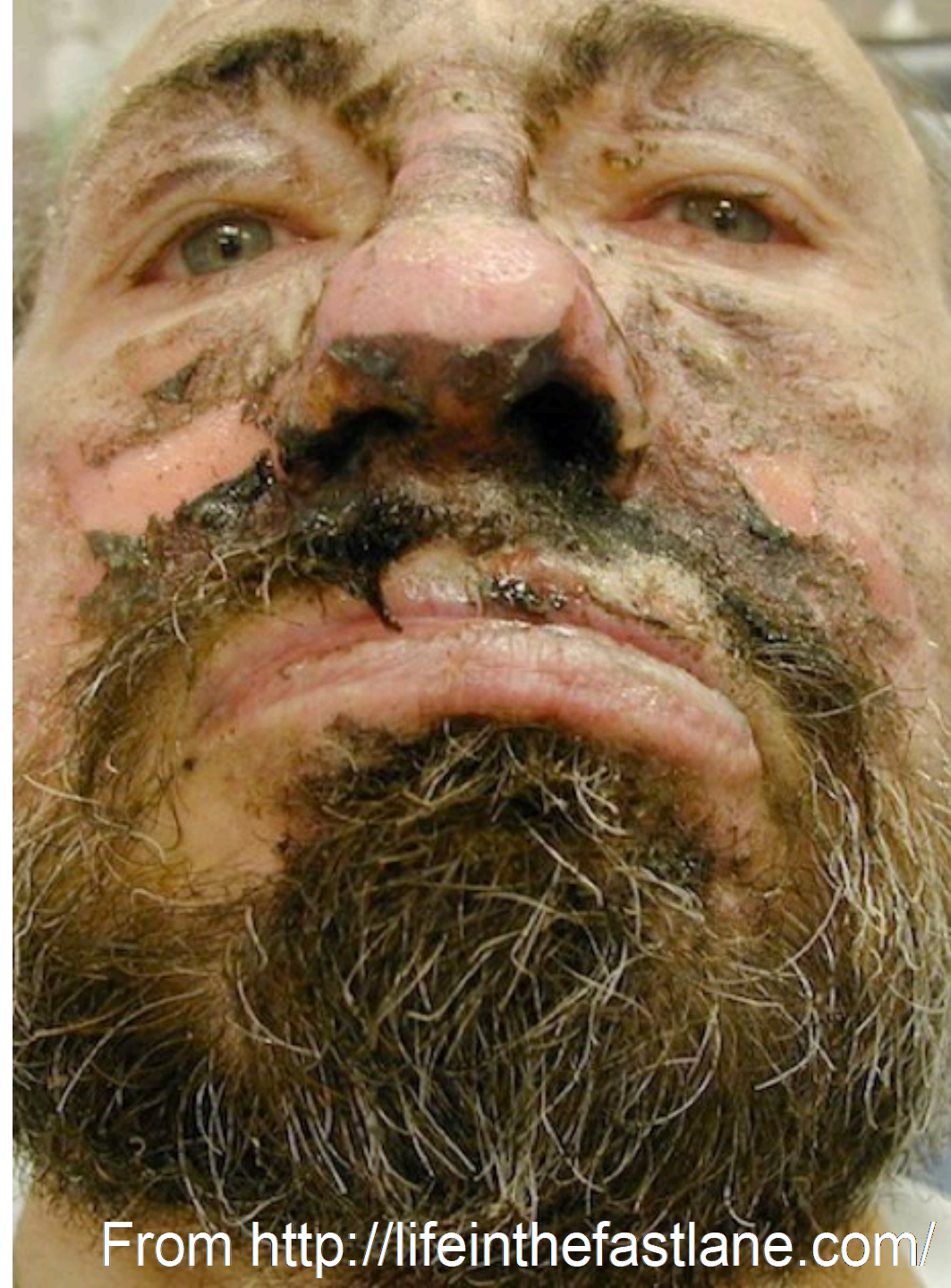
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From <http://lifeinthefastlane.com/>

Case #1

- A 40-year-old male is pulled from an enclosed fire.
- Confused and agitated
- Coughing up soot and complaining of difficulty breathing.
- BP 90/60, HR 120, RR 30, O2 sat 95% on RA
- Laboratory Data:
 - VBG: pH 7.0, pO2 45, Lactate 16 mmol/L
 - **COHgb: 20%**



From <http://lifeinthefastlane.com/>

Don't Forget About Cyanide...

- Hydrogen cyanide gas is produced in the combustion of :



Paper



Silk



Wool



Plastic



Cotton

Public Health

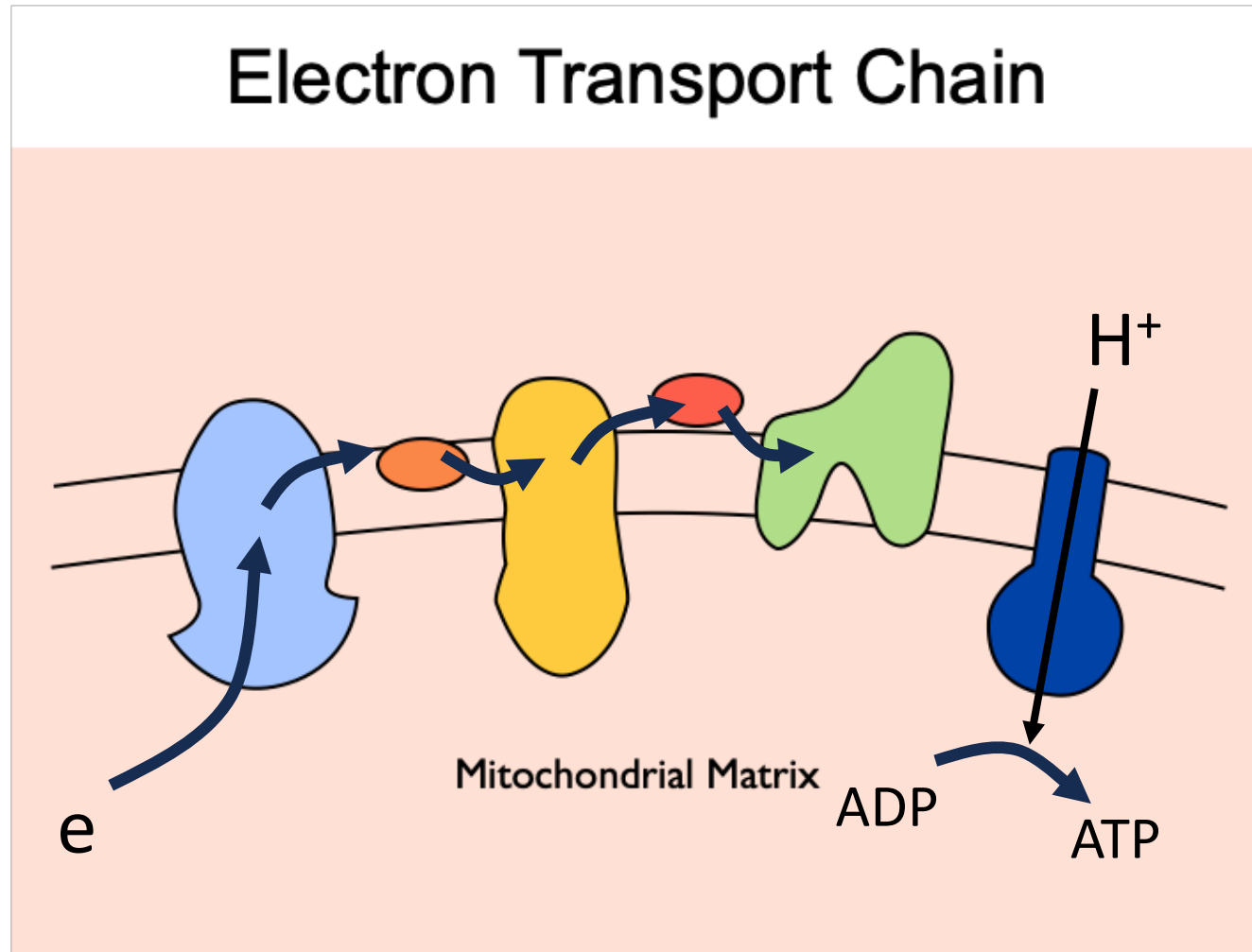
CYANIDE EXPOSURE IN FIRES

I. S. SYMINGTON

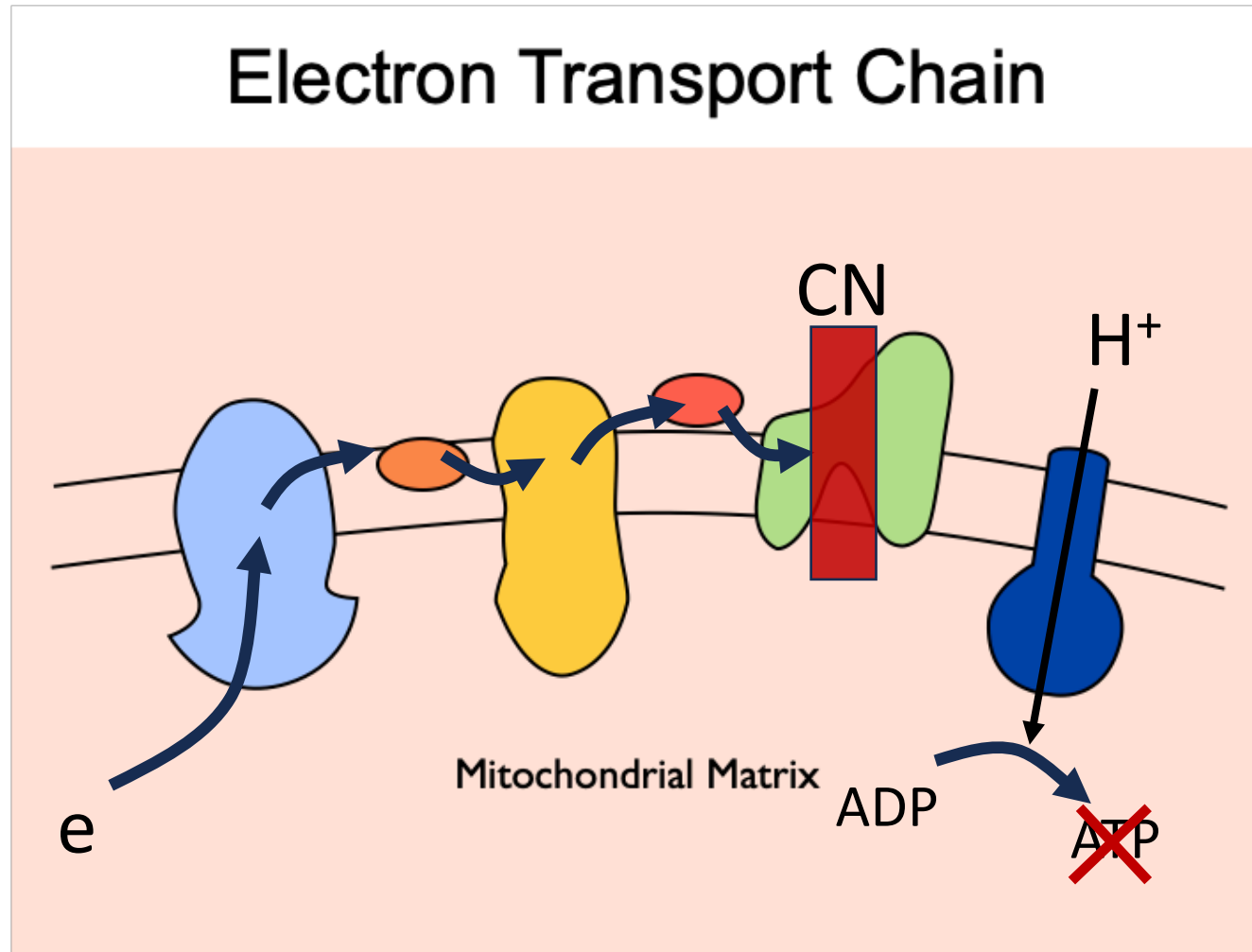
*Employment Medical Advisory Service, Health and Safety
Executive, Overgate House, 121 Market Gait, Dundee*

Subject group	Cyanide ($\mu\text{mol/l}$)			
	No. in group	Range	Mean	S.D.
Control non-smokers	29	0–11.7	2.9	2.4
Control smokers	27	1.3–19.4	6.8	4.2
Firemen non-smokers	30	0.1–14.9	3.6	3.5
Firemen smokers	64	0.5–22.9	8.5	5.2
Non-fatal-casualty non-smokers	11	0–29.0	10.4	8.0
Non-fatal-casualty smokers	10	3.8–22.6	13.2	6.3
Fatalities	52	0–130	25.3	27.9

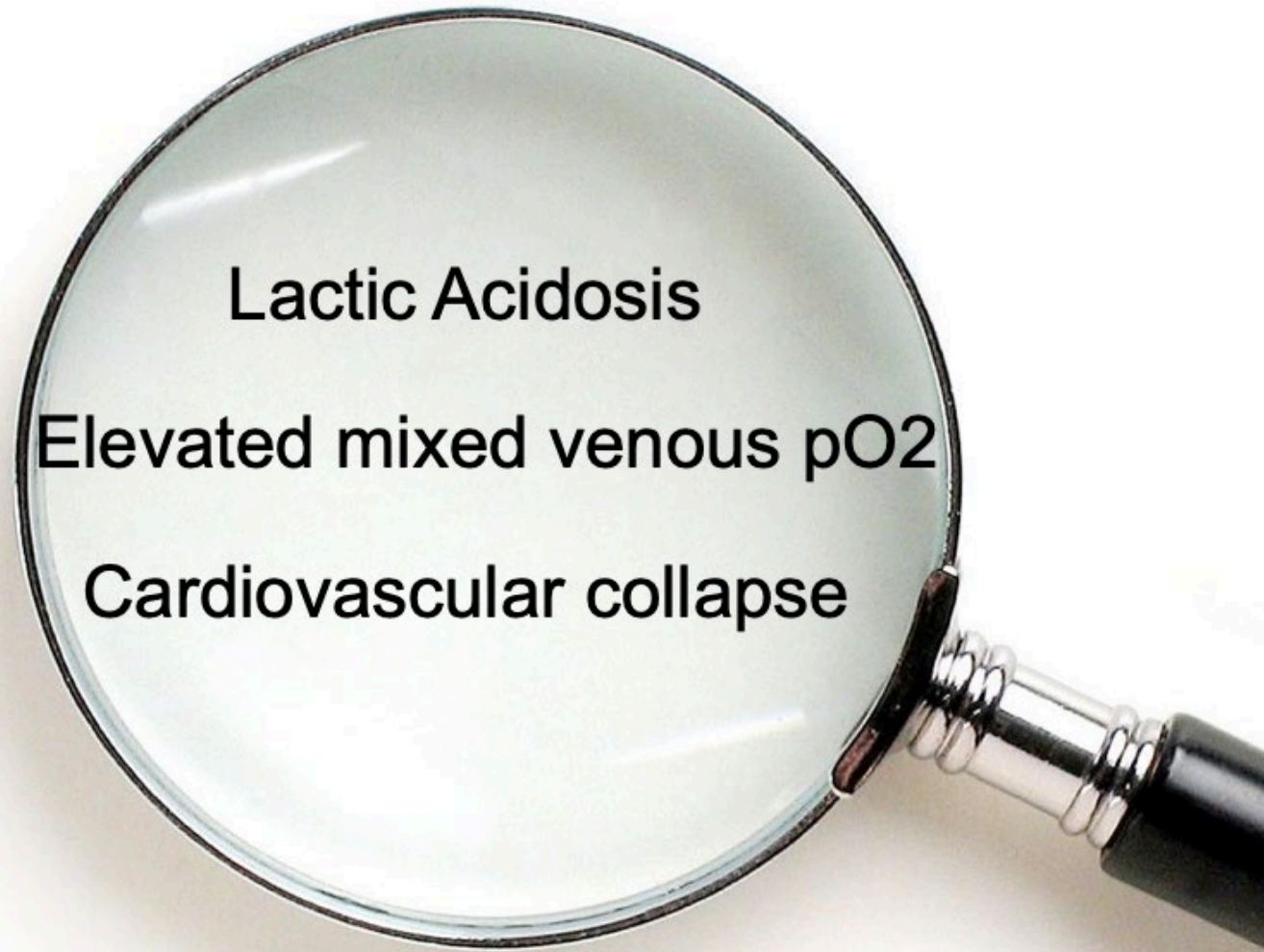
Cyanide Pathophysiology



Cyanide Pathophysiology



Cyanide: Clues to the Diagnosis



Lactic Acidosis

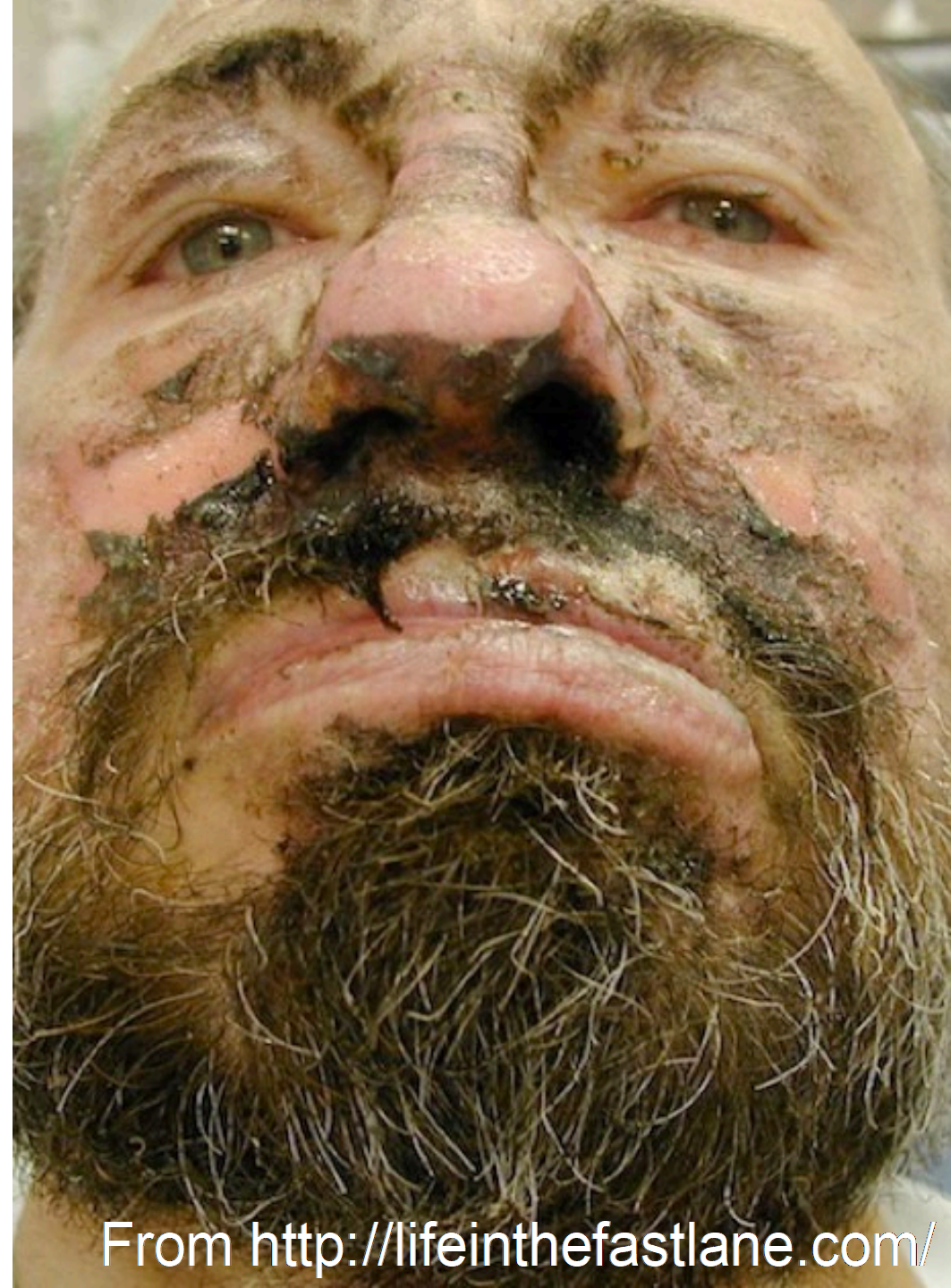
Elevated mixed venous pO₂

Cardiovascular collapse

Case #1

- A 40-year-old male is pulled from an enclosed fire.
- Confused and agitated
- Coughing up soot and complaining of difficulty breathing.
- BP 90/60, HR 120, RR 30, O2 sat 95% on RA
- Laboratory Data:
 - VBG: pH 7.0, pO2 45, **Lactate 16 mmol/L**
 - **COHgb: 20%**

Possible exposure to both CO and CN!!



From <http://lifeinthefastlane.com/>

Myocardial Injury and Long-term Mortality Following Moderate to Severe Carbon Monoxide Poisoning

Christopher R. Henry, BS

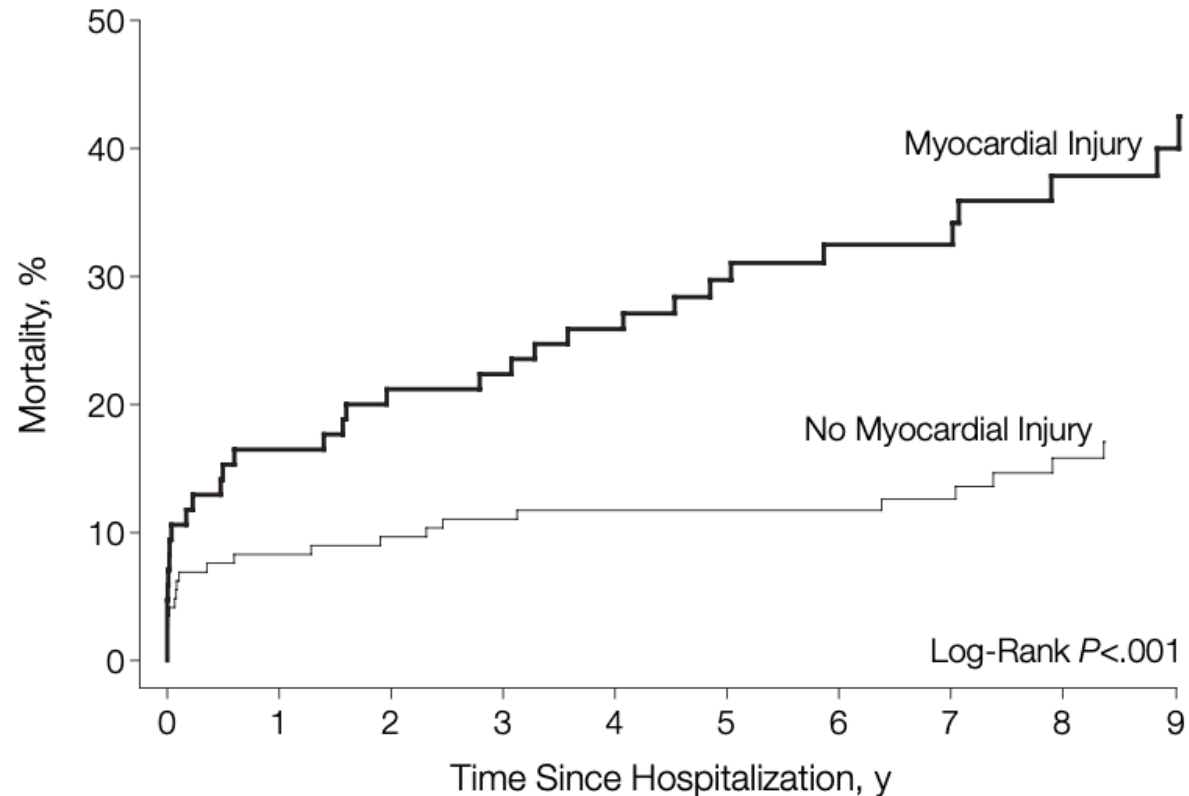
Daniel Satran, MD

Bruce Lindgren, MS

Cheryl Adkinson, MD

Caren I. Nicholson, RN

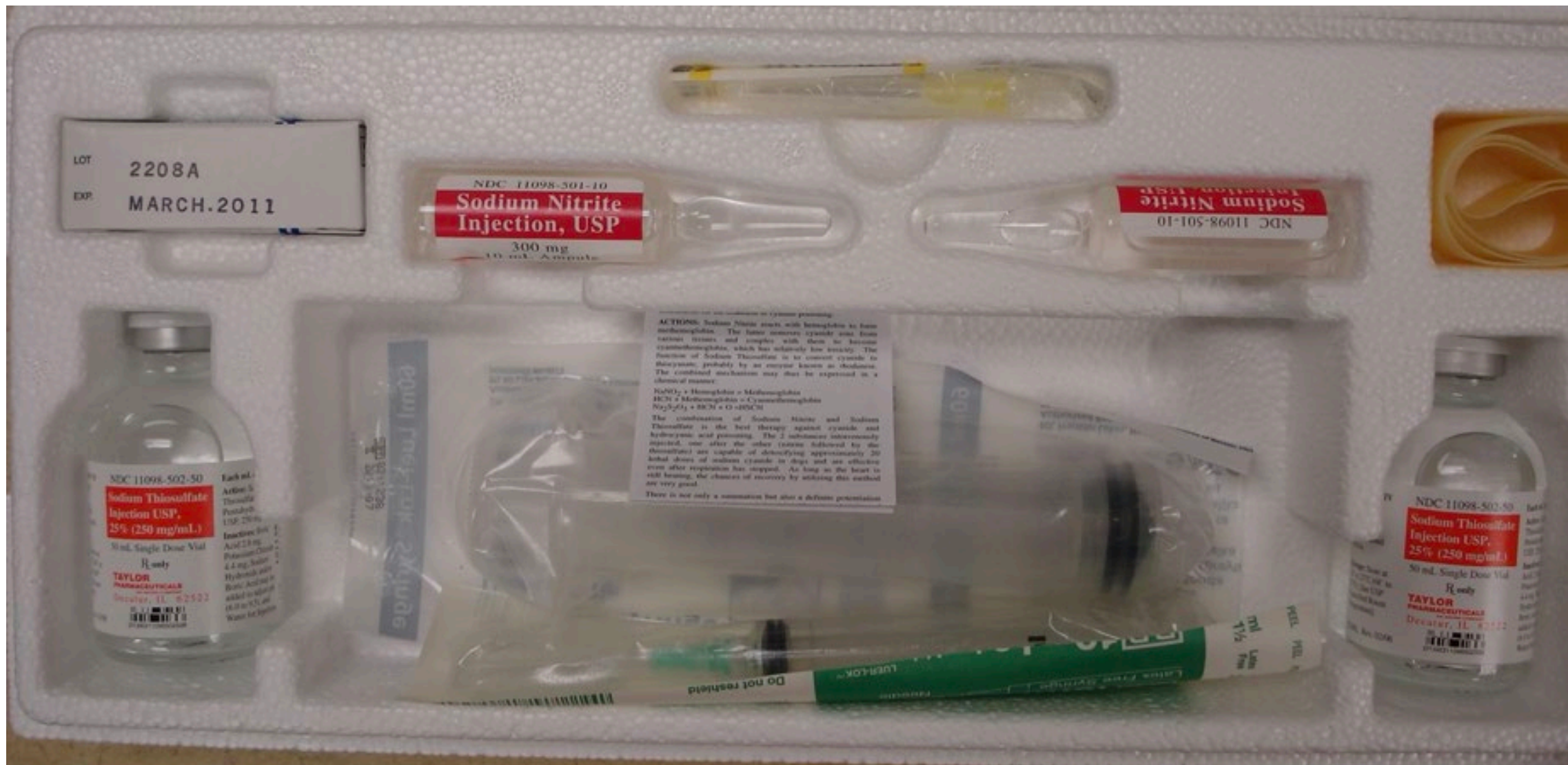
Timothy D. Henry, MD



Treatment Considerations – Cyanide

- Removal from the source
- 100% oxygen
- Consider early intubation
- Antidotes – Cyanide antidote kit vs. Hydroxocobalamin

Cyanide Antidote Kit



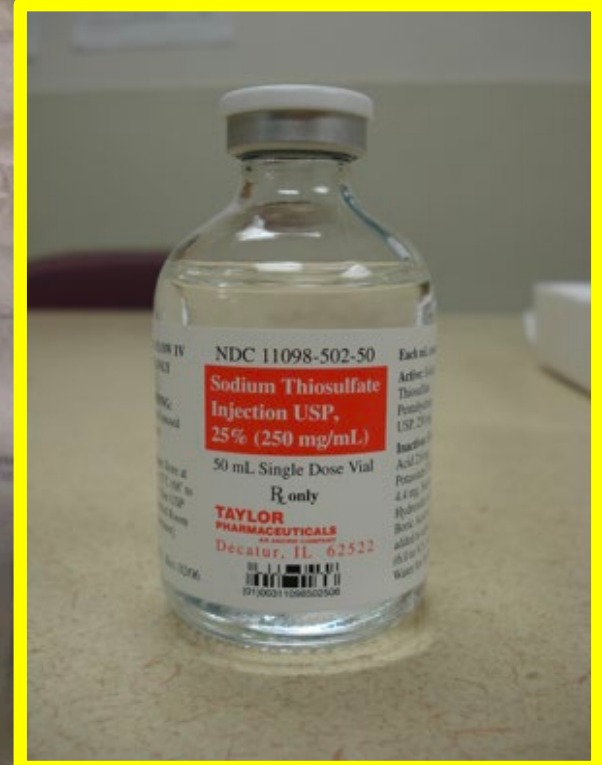
Cyanide Antidote Kit



Amyl Nitrite



Sodium Nitrite



Sodium Thiosulfate

Hydroxocobalamin

- Combines with CN to form Vitamin B12
- Appears to be effective and safe
- Preferred drug over nitrites (better safety profile)



Hydroxocobalamin

- Side effects:
 - Red skin and secretions (2-7 days)
 - Nausea, vomiting
 - Occasional HTN and muscle twitching



Day 1



Day 8



Treatment Considerations – Carbon Monoxide

- Removal from the source
- 100% oxygen by tight fitting mask vs. Intubation
- Hyperbaric Oxygen Therapy??

Oxygen Treatment	Approx $T^{1/2}$ of COHgb
• Room air	5-6 hrs
• 100% Oxygen	45-90 min
• Hyperbaric oxygen	20-30 min

Hyperbaric Oxygen Therapy

- Speedier removal of CO
- Provides oxygen independent of hemoglobin
- Benefits the injured brain?
- About 1,500 patients treated/year in the U.S.
- Million Dollar Question:
 - Does HBO reduce the incidence of subtle cognitive deficits (DNS)



Multiplace Chamber – Jacobi Hospital, NY





Monoplace Chamber

Weighing the Evidence – Human Studies

Study	Design	Max HBO pressure	Odds Ratio
Raphael, et. al 1989	HBO 2h vs 6h NBO	2.0 ATA	0.93 (0.57-1.49)
Mathieu, et. al 1996	HBO 90min vs 12h NBO	2.5 ATA	0.83 (0.57-1.22)
Thom, et.al. 1995	HBO 2h vs 100% NBO until asympt.	2.8 ATA	0.05 (0.00 – 0.95)
Scheinkestel et. al 1999	HBO 1h (x3) vs NBO 100 min x 3 days	2.8 ATA	1.00 (0.42-2.38)
Weaver, et al 2007	HBO 2h (x3) vs NBO 2h (x1)	3.0 ATA	0.39 (0.20-0.78)
Annane, et al 2011	HBO 2h vs NBO 6 h	2.0 ATA	1.08 (0.58-2.00)

Unfavorable Cognitive Outcome at 4-6 Weeks After Exposure to Carbon Monoxide In Randomized Clinical Trials of Hyperbaric Oxygen

Consider HBO if:

- Loss of consciousness
- COHbg level > 25%
- Age > 36 yrs
- Metabolic acidosis
- Cerebellar findings on exam
- Pregnancy (fetus more at risk)



- Clinical Policy: Critical Issues in the Evaluation and Management of Adult Patients Presenting to the Emergency department With Acute Carbon Monoxide Poisoning (2016)
- Does HBO therapy as compared with normobaric oxygen therapy improve long-term neurocognitive outcomes?
- **Level B Recommendation: Use HBO therapy or high-flow normobaric oxygen.**

Take Home Points

- Carbon Monoxide
 - Common component of smoke
 - Don't use non-invasive pulse CO oximetry to rule-in or rule-out
 - Troponin and abnormal ECG are prognostic markers for mortality
 - Treatment is oxygen (Either HBO or normobaric)
- Cyanide
 - Often accompanies CO in smoke inhalation
 - Elevated lactates are a clue to the diagnosis
 - Hydroxocobalamin is the preferred treatment

Questions?

