Target Audience: Emergency Medicine Residents (junior and senior level postgraduate learners), Medical Students

Primary Learning Objectives:
1. Demonstrate how to take an appropriate occupational history
2. Develop a list of "high risk" differential diagnoses for headache
3. Demonstrate how to recognize mild, moderate, severe CO poisoning
4. Treat a patient with severe CO poisoning appropriately

Secondary Learning Objectives: detailed technical/behavioral goals, didactic points
1. Appropriately uses available resources (poison center)
2. Communicates clearly and effectively while resuscitating a sick patient

Critical actions checklist:
1. Obtain peripheral IV access
2. Place on cardiac monitor
3. Order serum carboxyhemoglobin level and basic metabolic panel
4. Provide high-flow supplemental oxygen
5. Order head CT
6. Consult hyperbaric specialist
7. Consult Poison Center/Toxicologist
8. Admit/transfer to the MICU/hyperbaric center for definitive care

Environment: Emergency Department treatment area
    1. Room Set Up – ED critical care area
        a. Manikin Set Up – Mid or high fidelity simulator
        b. Props – Standard ED equipment
    2. Distractors – ED noise, alarming monitor

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CASE SUMMARY

SYNOPSIS OF HISTORY/ Scenario Background

Chief Complaint: Found unconscious; complaining earlier of syncope and headache

This is a case of a 23-year-old man presenting with altered mental status after complaining of headache and syncope while he was at work. **(The following history is only given to health care provider if specifically asked - patient is a construction worker in a building undergoing remodeling, using a generator to power several tools.)** He had started with a mild headache that had slowly progressed through the day. Later in the day, he felt lightheaded, dizzy, and passed out. His coworkers brought him to the ED. He reports nausea with associated vomiting (once). He reported general malaise and generalized weakness. He reports no fever, no cough, no vomiting or diarrhea, or any other pains or problems. He reports no trauma. There is no prior history of anticoagulant use, no neck stiffness, and no prior history of headaches. A co-worker had some acetaminophen that he took for the headache earlier in the workday, but the patient has told coworkers that this had not helped.

By the time the patient is brought to the ED, he demonstrates considerable confusion, lethargy, and mental status depression (he was found unconscious in the room in which he was working).

PMHx: None

PSHx: None

Medications: Acetaminophen

Allergies: None

SH: Unmarried
Denies ethanol, tobacco, or recreational drug use.

FH: None

Required Actions within the First Two Minutes

- Obtain HPI and essential ROS
- Establish safety net (IV, oxygen, cardiac monitor, two large bore IVs, draw blood for labs)
- A/B – Provide high-flow supplemental oxygen
- C – Cardiac monitor; NS IV bolus; ECG
- D – Point-of-care glucose = 100 mg/dL

CASE CONTINUATION - PHYSICAL EXAM

General Appearance: Decreased level of consciousness, appears unwell.

Vital Signs: BP: 123/82 mmHg P: 85/minute R: 22/minute T: 37.2C (98.9F) POx: 95% (FiO_2=0.21)

HEENT: Normal. Appears to be protecting airway at the beginning of the case

Neck: No tenderness or deformity on exam, full range of motion, no JVD

Skin: Warm and well-perfused, no rash.

Chest/CVS: Regular rate and rhythm. Normal heart sounds, no murmurs.

Lungs: Breath sounds present in all anterior and posterior lung fields. No adventitious sounds.

Back: Normal

Abdomen: Soft, non-tender, and non-distended. No guarding, rebound, or rigidity.

Extremities: Normal

Neurologic: Decreased level of consciousness. Lethargic, obtunded and confused. Rouses to touch, but markedly confused (groaning and garbled words only).

Required Actions within the Next Two Minutes

- Laboratory studies (especially point-of-care glucose and carboxyhemoglobin) should be ordered and sent by this time
- An ECG should be obtained by this time
- Empiric administration of dextrose or naloxone could be considered at this time
- CT head may be considered at this time

Branch Points

- **IF PATIENT RECEIVES EMPIRIC NALOXONE,** there will be no change in the patient's status.
- **IF PATIENT RECEIVES EMPIRIC DEXTROSE,** there will be no change in the patient's status.
- **IF NO SUPPLEMENTAL OXYGEN IS ADMINISTERED BY THIS TIME, THERE THE PATIENT WILL BEGIN TO SEIZE AND ENDOTRACHEAL INTUBATION WILL BE REQUIRED TO SECURE THE PATIENT'S AIRWAY.**
- **IF PATIENT RECEIVES EMPIRIC HYDROXOCOBALAMIN,** there will be no change in the patient's status.

Required Actions within the Next Several Minutes

- Labs return, notable for elevated carboxyhemoglobin level
- CT head, if ordered and performed, will reveal no evidence of mass, abscess, shift, or hemorrhage.
- Poison Center/Toxicologist and/or hyperbaric consultation should be obtained by this time
- **AT FACULTY DISCRETION, PATIENT COULD BE MADE TO SEIZE (REGARDLESS OF INTERVENTIONS PERFORMED) AT THIS TIME.**

Branch Points

- **IF THE PATIENT SEIZES AND ANTIEPILEPTIC MEDICATIONS ARE ADMINISTERED, THE SEIZURE WILL STOP.**
  - **NOTE: the patient's airway will now be unprotected and endotracheal intubation should be performed as the optimal route for high-flow supplemental oxygen administration.**
- **IF PARTICIPANTS CONTACT HYPERBARIC SPECIALIST,** then the patient's status will remain stable (if intubated) to allow the transfer to occur (depending on local institutional capabilities).
- **IF PARTICIPANTS CONTACT THE MICU,** then the intensivist will request consultation with the Poison Center/Toxicologist +/or the Hyperbaric specialist prior to accepting the patient for admission.

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CRITICAL ACTIONS

1. **Obtain peripheral IV access**

   Obtain peripheral IV access. Patient will require this access for medication and fluid boluses as the case progresses.
   Cueing Guideline: Nurse can ask if the doctor wants an IV inserted and blood for testing.

2. **Place on cardiac monitor**

   Place on cardiac monitor.
   Cueing Guideline: Nurse can ask if the doctor wants the patient placed on a cardiac monitor and other adjuncts.

3. **Order serum carboxyhemoglobin level and point-of-care serum glucose level**

   Order serum carboxyhemoglobin level and point-of-care serum glucose level.
   Cueing Guideline: The nurse asks if the doctor wants any diagnostic tests for the patient with a history of syncope and acute mental status change.

4. **Provide high-flow supplemental oxygen**

   Provide high-flow supplemental oxygen. Participants may accomplish this critical action by using a non-rebreather mask, other high-flow delivery device or through endotracheal intubation (this will be the preferred route if the patient seizes).
   Cueing Guideline: The nurse asks if the doctor about the concerning heart rate, and if anything could be done to improve the patient's status.

5. **Order head CT**

   Order head CT. Note that although this intervention is a critical action, it will be non-diagnostic in this case (there will be no mass, shift, or hemorrhage).
   Cueing Guideline: The nurse asks if the doctor about the patient's concerning mental status (especially if a seizure has occurred), and what the possible causes are.

6. **Consult hyperbaric specialist**

   Consult hyperbaric specialist.
   Cueing Guideline: The nurse asks if the doctor about the patient's concerning carboxyhemoglobin level.

7. Consult Poison Center/Toxicologist

The Poison Center or Toxicologist should be consulted for further management recommendations regarding carbon monoxide toxicity.
Cueing Guideline: The nurse can ask if the doctor has called the Poison Center or Toxicologist yet.

8. Admit/transfer to the MICU/hyperbaric center for definitive care

Admit/transfer to the MICU/hyperbaric center for definitive care. A discussion with the intensivist or the hyperbaric specialist regarding admission/transfer is required prior to the completion of the case.
Cueing Guideline: The nurse can ask if there is a definitive disposition for the patient yet.

Critical Actions Checklist[1]

Resident Name	
Case Description	

Skills measured **Core competencies: PC** Patient care, **MK** Medical knowledge, **IC** Interpersonal and communication skills **P** Professionalism, **PB** Practice-based learning and improvement **SB** Systems-based practice	Very Unacceptable		Unacceptable		Acceptable		Very Acceptable	
Data Acquisition (D) PC MK I	1	2	3	4	5	6	7	8
Problem Solving (S) PC MK PB	1	2	3	4	5	6	7	8
Patient Management (M) PC MK IC P PB SB	1	2	3	4	5	6	7	8
Resource Utilization (R) PC PB SB	1	2	3	4	5	6	7	8
Health Care Provided (H) PC SB	1	2	3	4	5	6	7	8
Interpersonal Relations (I) IC P	1	2	3	4	5	6	7	8
Comprehension of Pathophysiology (P) MK PB	1	2	3	4	5	6	7	8
Clinical Competence (C) PC MK IC P PB SB	1	2	3	4	5	6	7	8

Critical Actions

Yes	No		Comments:
		Obtain peripheral IV access	
		Place on cardiac monitor	
		Order serum carboxyhemoglobin level and basic metabolic panel	
		Provide high-flow supplemental oxygen	
		Order head CT	
		Consult hyperbaric specialist	
		Consult Poison Center/Toxicologist	
		Admit/transfer to the MICU/hyperbaric center for definitive care	

Yes	No	Dangerous actions

[1] Modified ABEM Oral Certification Examination checklist and scoresheet

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STIMULUS INVENTORY

#1 Complete blood count

#2 Basic metabolic panel

#3 Urinalysis

#4 Liver function tests

#5 Venous blood gas

#6 Toxicology

#7 Coagulation studies

#8 Carboxyhemoglobin level

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LAB DATA & IMAGING RESULTS

Stimulus #1	
Complete Blood Count (CBC)	
WBC	9,700/mm^3
Hemoglobin	14.2 g/dL
Hematocrit	42%
Platelets	297,000/mm^3
Differential	
PMNLs	75%
Lymphocytes	22%
Monocytes	2%
Eosinophils	1%

Stimulus #2A	
Basic Metabolic Panel (BMP)	
Sodium	134 mEq/L
Potassium	4 mEq/L
Chloride	105 mEq/L
Bicarbonate	15 mEq/L
Glucose	100 mg/dL
BUN	14 mg/dL
Creatinine	0.9 mg/dL

Stimulus #3	
Urinalysis	
Color	Yellow
Specific gravity	1.030
Glucose	Negative
Protein	Negative
Ketones	Negative
LE/Nitrites	Negative
Blood	Negative
WBC/RBC	0/hpf / 0/hpf
Crystals/bacteria	Negative

Stimulus #4	
Liver Function Tests	
AST	49 IU/L
ALT	32 IU/L
ALP	110 IU/L
T. Bilirubin	1.2 mg/dL
D. Bilirubin	0.2 mg/dL
Albumin	4.3 mg/dL

Stimulus #5	
Venous Blood Gas	
pH	7.31
pCO_2	47 mmHg
pO_2	36 mmHg
HCO_3	15 mEq/L
Lactate	4.5 mmol/L

Stimulus #6	
Toxicology	
APAP / ASA	Undetectable
Ethanol	Undetectable

Stimulus #7	
Coagulation Studies	
PTT	28 seconds
INR	0.99

Stimulus #8	
Carboxyhemoglobin	
Value	40%

Stimulus #1

Complete Blood Count (CBC)

WBC	9,700/mm^3
Hemoglobin	14.2 g/dL
Hematocrit	42%
Platelets	297,000/mm^3
Differential	
PMNLs	75%
Lymphocytes	22%
Monocytes	2%
Eosinophils	1%

Stimulus #2

Basic Metabolic Panel (BMP)

Sodium	134 mEq/L
Potassium	4 mEq/L
Chloride	105 mEq/L
Bicarbonate	15 mEq/L
Glucose	100 mg/dL
BUN	14 mg/dL
Creatinine	0.9 mg/dL

Stimulus #3

Urinalysis

Color / pH	Yellow
Specific gravity	1.030
Glucose	Negative
Protein	Negative
Ketones	Negative
LE/Nitrites	Negative
Blood	Negative
WBC/RBC	0/hpf / 0/hpf
Crystals/bacteria	Negative

Stimulus #4

Liver Function Tests

AST	49 IU/L
ALT	32 IU/L
ALP	110 IU/L
T. Bilirubin	1.2 mg/dL
D. Bilirubin	0.2 mg/dL
Albumin	4.3 mg/dL

Stimulus #5

Venous Blood Gas

pH	7.31
pCO_2	47 mmHg
pO_2	36 mmHg
HCO_3	15 mEq/L
Lactate	4.5 mmol/L

Stimulus #6

Toxicology

APAP / ASA	Undetectable
Ethanol	Undetectable

Stimulus #7

Coagulation Studies

PTT	28 seconds
INR	0.99

Stimulus #8

Carboxyhemoglobin

Value	40%

Debriefing Materials – <u>Carbon Monoxide Toxicity</u>

Educational Goal: To review the key principles of the diagnosis and management of carbon monoxide poisoning

Debriefing Method

I. Decompress – "How did you feel it went?" (not asking for details; just a chance for the resident to decompress, decrease anxiety/energy level to be more open to learning/retaining knowledge)
II. Core Medical Knowledge (instructor covers details of scenario and objectives)
III. Advocacy/Inquiry
    a. As an instructor "advocate" for your point of view/observations of resident action
    b. Inquire with an open mind to see why the resident acted the way they did – use this response as a springboard to determine what exactly to teach (e.g., was the resident's poor performance due to missing core medical knowledge or is it a lack of communication skills with the rest of the team?)
IV. Plus/Delta
    a. Plus – tell the resident what went well
    b. Delta – Tell the resident what she could change for next time

Teaching Points:

Carbon monoxide (CO) is an odorless, colorless gas with a greater affinity than oxygen for hemoglobin. and is one of the most common causes of unintentional poisoning deaths in the United States. CO is produced by the incomplete combustion of carbon-containing fuels and can result from house fires and engines. Unintentional exposures peak during colder months due to increased use of alternative in-door heating sources and reduced ventilation. Symptom onset is usually insidious and vague, but can be dramatic in severe toxicity. Hypoxia results from carboxyhemoglobinemia, but other mechanisms cause toxicity, including inflammatory cascades. Treatment is based on supportive care with unclear guidelines for further definitive interventions, such as hyperbaric oxygen therapy.

Symptoms are generally vague and include nausea, vomiting, headache, fatigue, and flu-like symptoms. In severe exposures patients may present with chest pain, altered mental status, syncope, and seizures.

The primary treatment modalities for patients experiencing CO poisoning include removing the patient from the source, standard supportive care, and oxygen administration.

CO toxicity is diagnosed by history and lab findings – specifically, getting a VBG w/ co-oximetry to directly measure a carboxyhemoglobin (COHb) level. Although the COHb level can lead to a diagnosis, the actual percentage poorly correlates with the clinical signs and symptoms. Note also that nonsmokers have levels of <1.5%, while heavy smokers will have higher baseline COHb levels (between 3-10%).

Oxygen administration enhances CO elimination from the body by decreasing the CO elimination half-life. Examples are room air: 4-5 hours; 100% O2 by NRB mask: 60-90 min; hyperbaric oxygen (HBO): about 25 minutes.

Indications for HBO therapy are controversial. Although it is logical that if oxygen supplementation is good, then more oxygen should be better, the few published clinical trials

show mixed results. Proponents for HBO therapy point to decreased rates of delayed neurologic sequelae in patients treated with HBO vs normobaric oxygen. However, the data are conflicting, and two studies showed no difference between HBO and normobaric oxygen.

2011 Cochrane Collaboration Review: [1] "Existing randomized trials do not establish whether the administration of HBO to patients with carbon monoxide poisoning reduces the incidence of adverse neurologic outcomes. Additional research is needed to better define the role, if any, of HBO in the treatment of patients with carbon monoxide poisoning."

2008 ACEP Clinical Policy (Level C recommendation): [3]

1. HBO is a therapeutic option for CO-poisoned patients; however, its use cannot be mandated.
2. No clinical variables, including carboxyhemoglobin levels, identify a subgroup of CO-poisoned patients for whom HBO is most likely to provide benefit or cause harm.

In contrast, the **Undersea and Hyperbaric Medical Society** does recommend HBO therapy for patients with any of the following: [2]

- Transient or prolonged loss of consciousness
- Abnormal cerebellar exam
- Myocardial ischemia
- Severe acidosis
- Age over 36 years
- CO exposure of ≥24 hours
- Carboxyhemoglobin level ≥25%

Regarding pregnant patients, no clinical trial has assessed the efficacy and safety of HBO. Nevertheless, in weighing risks and benefits, commonly accepted recommendations for HBO therapy in pregnancy include the following:

- Maternal COHb level ≥15-20%
- Evidence of fetal distress
- Any of the other "standard" criteria

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Wolf SJ, Lavonas EJ, Sloan EP, Jagoda AS; American College of Emergency Physicians. Clinical policy: Critical issues in the management of adult patients presenting to the emergency department with acute carbon monoxide poisoning. Ann Emerg Med. 2008 Feb;51(2):138-52.

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