

SMOKE

Cyanide and Carbon Monoxide:
The Toxic Twins of Smoke Inhalation





Cyanide Exposure, Smoke Inhalation, and Pre-Hospital Treatment: Recognizing the Signs and Symptoms and Available Treatment Options

by Daniel J. O'Brien, MD, FACEP, James Augustine, MD, FACEP, and Donald W. Walsh, PhD, EMT-P

The preceding articles cover the toxic composition of smoke, means of improving firefighting operations to reduce smoke toxicity, and the need for effective interventions to reduce smoke-related toxicity. This article describes the signs and symptoms of cyanide exposure and discusses the importance of a comprehensive smoke inhalation assessment and treatment protocol for improving outcomes in smoke-associated cyanide poisoning.

Context

Both civilians and firefighters die as a result of inhalation of products of combustion from fire. Cyanide is one of the products of combustion that will contribute significantly to inhalation injury and death. Hydrogen cyanide, a toxic product of combustion of common nitrogen and carbon-containing substances, is likely to be generated under the conditions of high temperature and low oxygen that characterize closed-space structure fires.

Research on victims of smoke inhalation indicates that cyanide poisoning may be an important agent of death, particularly for victims in closed-space fires. For example, studies that simulated the nightclub fire in Rhode Island found rapid buildup of heat, carbon monoxide and cyanide to levels incompatible with survival. Cyanide poisoning can be treated effectively if it is recognized promptly and if intervention is initiated immediately. In this context, it is impor-

tant that pre-hospital providers recognize the signs and symptoms of cyanide poisoning and have smoke inhalation evaluation and treatment protocols in place.

Mechanisms and Manifestations of Cyanide Toxicity

Cyanide causes human toxicity by deactivating the mechanisms that allow cells to utilize oxygen. Because cyanide-poisoned cells are unable to use oxygen, they transition from aerobic metabolism to anaerobic metabolism and generate toxic by-products, such as lactic acid. Organs such as the heart and brain, which rely on a substantial, continuous supply of oxygen, are quickly affected by cyanide poisoning. Exposure to smaller concentrations can initially cause respiratory activation (manifested by rapid breathing and tachycardia) in an attempt to compensate for lack of oxygen. Early manifestations include headache, anxiety, blurry vision, and loss of judgment. As cyanide accumulates further, signs and symptoms of poisoning reflect the effects of oxygen deprivation on the heart and brain. These include cardiac dysrhythmias, seizure, coma, and death. The time between exposure and incapacitation or death is typically minutes, but varies depending on the concentration of cyanide and other toxicants. Many toxicants affect oxygen utilization. The presence of multiple toxicants in fire smoke can be particularly hazardous.

Recognizing Acute Cyanide Poisoning

Currently, there is no diagnostic test to confirm cyanide poisoning within the limited window for initiating potentially lifesaving intervention. Transcutaneous monitors, such as those used to detect carbon monoxide poisoning, might some day be available to quantify the level of cyanide attached to hemoglobin; however, such an assessment tool is not currently available. Therefore, in the pre-hospital setting, acute cyanide poisoning must be diagnosed presumptively.

Cyanide poisoning should be suspected in any person exposed to smoke in a closed-space fire. The simultaneous presence of hypotension increases confidence in the diagnosis of cyanide poisoning. A few cyanide-poisoned victims have a pinkish to cherry-red complexion caused by the (abnormal) high oxygenation of venous blood. The victim's breath may have an almond-like odor attributed to excretion of small amounts of cyanide in the breath. However, many people cannot smell this odor, sometimes resulting in the failure of the pre-hospital provider to accurately diagnose cyanide poisoning.

At most hospitals, rapid measurements of cyanide are not available. Assessment and treatment rely primarily on clinical judgment. Hospital laboratory findings that may indicate a strong possibility of cyanide poisoning include:

- Metabolic acidosis
- Elevated plasma lactate concentrations caused by the accumulation of lactic

acid, a by-product of anaerobic metabolism

- Elevated oxygen content of venous blood, caused by failure of cyanide-poisoned cells to extract oxygen from arterial blood
- Carbon monoxide by blood tests or use of the transcutaneous monitor that is inconsistent with clinical symptoms.

It can be difficult to differentiate the effects of cyanide and carbon monoxide poisoning. The classic symptoms of poisoning with each agent are outlined in Tables 1 and 2. They are very similar. Detection of carbon monoxide poisoning can be achieved with the transcutaneous carbon monoxide oximeter (CO-oximeter). The assessment for cyanide poisoning in the smoke inhalation victim remains a matter of clinical assessment by the astute emergency provider.

Support for the Smoke

Inhalation Victim

Basic life support care for the smoke inhalation victim includes removing the victim from the source of exposure; providing cardiopulmonary support, warmth and fluids; administering 100 percent oxygen; and assuring appropriate ventilation. Nebulizer treatment with a bronchodilator may be given for wheezing.

The suspicion of acute cyanide poisoning should prompt the pre-hospital provider to consider antidote therapy. Advanced life support care includes anticonvulsants for seizures. The motor activity associated with seizures can aggravate acidosis. Victims, especially those with heart disease, may develop significant dysrhythmias. Correction of underlying metabolic abnormalities and antiarrhythmics, as warranted, should be administered to stabilize cardiovascular function. Initial management of shock should include fluids resuscitation. Prevention of hypothermia is a critical consideration. Severe acidosis may be a treatment consideration, and sodium bicarbonate may need to be administered

<p>Table 1: MANIFESTATIONS OF CYANIDE POISONING</p> <p>Early Indications of Exposure to Low Inhaled Concentrations:</p> <ul style="list-style-type: none"> <li style="width: 33%;">■ Anxiety <li style="width: 33%;">■ Drowsiness <li style="width: 33%;">■ Dyspnea <li style="width: 33%;">■ Headache <li style="width: 33%;">■ Impaired judgement <li style="width: 33%;">■ Tachycardia <li style="width: 33%;">■ Tachypnea <li style="width: 33%;">■ Vertigo <p>Inhalation of Moderate to High Concentrations:</p> <ul style="list-style-type: none"> <li style="width: 50%;">■ Cardiovascular collapse <li style="width: 50%;">■ Cardiac dysrhythmia <li style="width: 50%;">■ Hypotension <li style="width: 50%;">■ Markedly altered level of consciousness <li style="width: 50%;">■ Respiratory depression or arrest <li style="width: 50%;">■ Seizure <li style="width: 100%;">■ Smell of almonds on the breath (sometimes undetectable) 		
<p>Table 2: MANIFESTATIONS OF CARBON MONOXIDE POISONING</p> <p>Early Indications of Exposure to Low Inhaled Concentrations:</p> <ul style="list-style-type: none"> <li style="width: 50%;">■ Difficulty with balance <li style="width: 50%;">■ Fatigue <li style="width: 50%;">■ Headache <li style="width: 50%;">■ Palpitations <p>Inhalation of Moderate to High Concentrations:</p> <ul style="list-style-type: none"> <li style="width: 50%;">■ Altered level of consciousness <li style="width: 50%;">■ Cardiac dysrhythmia <li style="width: 50%;">■ Nausea and vomiting <li style="width: 50%;">■ Respiratory arrest <li style="width: 50%;">■ Seizure <li style="width: 50%;">■ Severe headache <li style="width: 50%;">■ Shock and death <li style="width: 50%;">■ Syncope 		

to reverse this state and improve the effectiveness of other therapies.

Transportation Considerations

Some communities have hospitals equipped to manage burn patients and/or provide hyperbaric oxygen treatment. In those communities, local medical control protocols typically prescribe the transportation of victims with burns and those with suspected carbon monoxide poisoning. The American Burn Association recommends, in part, that partial-thickness and full-thickness burns greater than 10 percent of the total body surface area in patients under 10 years old or over 50 should be transported to a burn center. Partial-thickness burns greater than 20 percent of the total body surface area in other age groups, and full-thickness burns greater than 5 percent of the total body surface area in any age group, or an inhalation injury, ideally should be transported to an adult or pediatric burn center. In communities that have multiple hospitals with different capabilities, EMS providers should preferentially transport smoke inhalation patients to those emergency departments that are prepared and equipped to man-

age burns, carbon monoxide inhalation, and cyanide poisoning. When in doubt, on-line medical control should be contacted and assistance requested in determining the correct destination hospital.

Protocols for Pre-Hospital Assessment and Treatment of the Smoke Inhalation Victim

Smoke-associated poisoning with cyanide and other toxicants can rapidly culminate in death. To ensure that smoke inhalation victims are appropriately evaluated and intervention is promptly provided, it is essential to have protocols in place for pre-hospital assessment and treatment of victims of smoke inhalation. The following sample protocol can be adapted to department- or facility-specific needs and capabilities:

Indications

The protocol applies to the patient who has been trapped or rescued from a closed-space structure fire. The presence of soot in the nose and/or mouth in the unconscious patient may be a strong indicator of cyanide poisoning. The protocol applies regardless of whether a con-

current injury or burn is present. Smoke inhalation can be a dangerous medical condition requiring prompt evaluation and treatment!

Patient Evaluation

The patient should be moved to an area safe for assessment and clinical management. Key elements of the evaluation include:

- Mental status
- Any concurrent burn
- Any concurrent severe or critical injury
- Degree of respiratory distress
- Ability to oxygenate

The patient's airway, breathing and mental status are evaluated as part of the primary assessment. Compromise of any of these elements makes the patient a "red category" triage victim and makes rapid treatment a priority. The patient requires support of airway, breathing and supplemental oxygen. The patient that has a sustained burn injury or other severe or critical traumatic injury should be given treatment specific to those medical presentations. In addition, a smoke inhalation treatment protocol should be initiated.

A pulse oximeter reading can assist in the evaluation of the patient's overall ability to perfuse the body with oxygen. In the presence of carbon monoxide exposure, the pulse oximeter alone may produce an incorrect reading as the device does not assess the percent of hemoglobin affected by carbon monoxide. A reading below 90 percent reflects ineffective breathing, direct injury to the airway or lungs, or severe underlying lung disease (or some combination of these elements). When available, the carbon monoxide oximeter detects the level of carbon monoxide attached to the victim's hemoglobin. A detector reading exceeding 12 percent reflects moderate carbon monoxide inhalation, and one exceeding 25 percent reflects severe inhalation. Smoke and other toxic products cause direct irritation of the airway and lungs, and treatment should reduce this irritation. Any injury to the airway or lungs causes impaired ability to oxygenate and



ventilate, and treatment should supplement oxygen delivery, protect the airway, and facilitate exhalation of toxins.

Emergency Treatment and Transportation

1. Perform a primary survey to evaluate airway, breathing, mental status, and the presence of burns or other injuries. If possible, obtain a patient history of any underlying heart or lung problems.
2. Evaluate the patient's oxygenation by pulse oximeter and listen to the lungs for any abnormal sounds, particularly wheezing. When available, obtain a CO-oximetry reading. Victims with carbon monoxide levels exceeding 25 percent should be preferentially transported to the appropriate receiving hospital.
3. Evaluate for potential cyanide toxicity. The patient should be evaluated for the presence of soot in the nose or mouth and/or an altered mental status, hypotension or shock, flushed skin, and seizures. These patients may be candidates for treatment with a cyanide antidote. Contact on-line medical control, if needed.
4. Treat any burn or traumatic injury. The spine should be immobilized if indicated. If there is no indication for immobilization, allow the victim to find his/her position of comfort. Significant inhalation will cause violent coughing and at times vomiting, so the victim should be placed in a protective position or in a position of comfort.
5. If the airway is compromised, the patient should undergo endotracheal intubation. If unsuccessful, a rescue device can be utilized.
6. Provide supplemental oxygen. Most victims with an inhalation injury do not tolerate dry oxygen; therefore, the oxygen line should have a nebulizer attached with a full container of saline as soon as possible. If mental status permits, allow the patient to self-administer the oxygen by holding the mask and sitting in a position of comfort.
7. If any wheezing is present on the lung evaluation or if the patient has a history of asthma or wheezing, administer nebulized Albuterol. The nebulizer should contain 2.5mg in

- 3ml of Albuterol premix and filled with normal saline. The patient should continue use of the nebulized Albuterol and saline until it is dry.
8. If there are a large number of victims and an oxygen distributor manifold is available, place the victims in the same area, set up the manifold with an appropriate number of oxygen masks, and obtain the large nebulizer cup. Place 6ml or two premix ampules of Albuterol in the cup, fill the cup with saline, and allow patients to self-administer the mixture by mask.
 9. Victims with mild smoke inhalation may be treated and released. To allow the victim to self-release from care, the following conditions must be met: mental status unimpaired or back to baseline for that individual (with verification by a friend or family member); no signs of respiratory distress and a pulse oximeter reading above 92 percent; lungs clear on auscultation; and no other significant burn or traumatic injury. Victims should be advised to seek medical attention if systems recur as some aftereffect of smoke inhalation injury may not be evident at the time of injury and only develop after several hours .



10. Victims with more severe smoke inhalation should be transported to the hospital.
 - For patients requiring transport to a hospital, appropriate treatment should occur in conjunction with the transport agency, and the patient should be turned-over for further assessment and interventions.
 - Symptoms of carbon monoxide poisoning require possible removal of the patient to a hospital with hyperbaric oxygen treatment capabilities. Evidence of carbon monoxide poisoning includes impaired mental status, neurologic compromise to include seizures, and a carbon monoxide reading over 25 percent.
 - Major burn injuries get precedence in the determination of a receiving facility. A significant burn injury (generally, any burn over 10 percent full-thickness, a respiratory burn, or a burn over 20 percent partial-thickness) requires transport to the appropriate adult or pediatric burn center.

When to Consider Empiric Management of Acute Cyanide Poisoning in Smoke Inhalation

Prior to the availability of Hydroxocobalamin, the empiric management of the cyanide toxicity associated with smoke inhalation was not a viable treatment option as the methemoglobin-inducing antidotes were contraindicated in carbon monoxide poisoning. All victims of smoke inhalation should be treated as previously outlined. Published experience with pre-hospital Hydroxocobalamin administration for presumed cyanide toxicity associated with smoke inhalation suggests that it may be an important supplemental tool in the management of smoke inhalation.

Clearly, not everyone exposed to fire smoke is at risk or warrants treatment. There are costs and complications associated with all medications, and prudence dictates that only those patients likely to

benefit should be exposed to the risks. Based on current clinical experience, there are historical and physical cues that suggest which victims may benefit from treatment.

Mild Smoke Inhalation

Victims with normal levels of consciousness, without hypotension and experiencing only headache, dyspnea, chest tightness, nausea, vomiting, and transient confusion do not require empiric management for cyanide intoxication. They should be managed as previously described.

Moderate Smoke Inhalation

Victims with altered levels of consciousness (GCS>8) without hypotension – even though they may be experiencing confusion and disorientation in addition to headache, dyspnea chest tightness or nausea – also do not appear to warrant empiric management for cyanide intoxication. These patients should be transported to the closest appropriate facility and monitored for any deterioration. Emergency department management may include the collection of 5ml or 7ml blood in an iced EDTA vacutainer for subsequent analysis for cyanide. The patients COHB level and serum lactate should be determined. Serum lactate levels >10mmol/l has a high correlation with cyanide toxicity and will likely be the only lab available to the clinician in determining the likelihood of cyanide exposure.

Severe Smoke Inhalation

Victims presenting with seizures or who are in a coma (GCS <8) with hypotension or impending cardiovascular collapse, mydriasis, dyspnea, nausea or vomiting should be considered candidates for empiric administration of Hydroxocobalamin 5gm IV over 15 minutes. In addition to managing the airway appropriately and providing adequate oxygenation and ventilation, two IV or IO lines should be established. Consideration should be given to obtaining 5ml to 7ml of blood in an iced EDTA vacutainer for subsequent analysis for cyanide.

Hydroxocobalamin may interfere with the accuracy of some laboratory values. Depending on local protocol, blood may be drawn for cardiac enzymes, serum lactate, and basic chemistries prior to the administration of the medication. Blood collection should not delay medication administration in any circumstance. The patient should be monitored enroute, with any hemodynamic or cardiac instability managed as appropriate. A second 5gm infusion may be considered based on clinical response.

Cardiac Arrest in Smoke Inhalation

There is very little experience in the clinical literature describing the management of victims of smoke inhalation in cardiac arrest with Hydroxocobalamin. All routine patient care, airway management and oxygenation should be accomplished according to currently accepted AHA guidelines. Likewise, all trauma protocols should be observed. Conceptually, carbon monoxide and cyanide toxicity associated with cardiac arrest secondary to smoke inhalation may be considered a potentially treatable oxygenation issue and should be treated with Hydroxocobalamin 5gm IV as early as possible in the cardiac arrest to combat tissue hypoxia that can not otherwise be addressed with CPR, cardioversion, defibrillation, or cardiac medications. Two IV or IO lines should be established. All AHA guidelines regarding CPR and rhythm management should otherwise be observed. Depending on clinical response, a second infusion of Hydroxocobalamin 5gm IV may be warranted.

Conclusions

Both prompt recognition of acute cyanide poisoning and immediate initiation of care are necessary for effective treatment. The fire professional often provides the first line of medical care for victims of smoke associated cyanide poisoning in the pre-hospital setting. By recognizing cyanide poisoning and efficiently initiating corrective measures according to protocol, the fire professional can save lives. 🙏

References:

1. Hall A, Rumack BH. *Clinical toxicology of cyanide*. Ann Emerg Med., 1986; 15: 1067-1074.
2. Jones J, McMullen MJ, Dougherty J. *Toxic smoke inhalation: Cyanide poisoning in fire victims*. Am J Emerg Med., 1987; 5: 317-321.
3. Silverman SH, Purdue GF, Hunt JL, et al. *Cyanide toxicity in burned patients*. J Trauma, 1988; 28: 171-176.
4. Kulig K. *Cyanide antidotes and fire toxicology*. N Engl J Med., 1991; 325: 1801-1802.
5. Baud F, Barriot P, Toffis V, et al. *Elevated blood cyanide concentrations in victims of smoke inhalation*. N Engl J Med., 1991; 325: 1761-1766.
6. Agency for Toxic Substances and Disease Registry. U.S. Department of Health and Human Services, Public Health Service. *Cyanide toxicity*. Am Fam Phys., 1993; 48: 107-114.
7. Houeto P, Hoffman JR, Imbert M, et al. *Relation of blood cyanide to plasma 18 cyanocobalamin concentration after a fixed dose of hydroxocobalamin in cyanide poisoning*. Lancet, 1995; 346: 605-608.
8. Borron SW, Vicaut E, Ruttimann M, et al. *Biological tolerance of Hydroxocobalamin in fire victims intoxicated by cyanide*. Intensive Care Medicine, 1997; 23: S181.
9. Lee-Chiong TL. *Smoke inhalation injury*. Postgrad Med., 1999; 105: 55-62.
10. Ferrari LA, Arado MG, Giannuzzi L, et al. *Hydrogen cyanide and carbon monoxide in blood of convicted dead in a polyurethane combustion: A proposition for the data analysis*. Forensic Sci Int., 2001; 121: 140-143.
11. Sauer SW, Keim ME. *Hydroxocobalamin: Improved public health readiness for cyanide disasters*. Ann Emerg Med., 2001; 37: 635-641.
12. Moriya F, Hashimoto Y. *Potential for error when assessing blood cyanide concentrations in fire victims*. J Forensic Sci., 2001; 46: 1421-1425.
13. Calafat AM, Stanfill SB. *Rapid quantitation of cyanide in whole blood by automated headspace gas chromatography*. J Chromatogr B Analyt Technol Biomed Life Sci., 2002; 772: 131-137.
14. Alarie Y. *Toxicity of fire smoke*. Crit Rev Toxicol., 2002; 32: 259-289.
15. Koschel MJ. *Where there's smoke, there may be cyanide*. Am J Nurs., 2002; 102: 39-42.
16. Borron SW, Baud FJ. *Toxicity, cyanide*. February 2003. Available at: www.emedicine.com/emerg/topic11.htm. Accessed May 2006.
17. Mégarbane B, Delahaye A, Goldgran-Tolédano D, et al. *Antidotal treatment of cyanide poisoning*. J Chin Med Assoc., 2003; 66: 193-203.
18. Gill JR, Goldfeder LB, Stajic M. *The happy land homicides: 87 deaths due to smoke inhalation*. J Forensic Sci. 2003; 48: 161-163.
19. Madrzykowski D. *The Station Nightclub Fire: Simulation of fire and smoke movement in laboratory reconstruction*. NIST, U.S. Department of Commerce. National Construction Safety Team Investigation. June 2004.
20. Eckstein M, Maniscalco P. *Focus on smoke inhalation – the most common cause of acute cyanide poisoning*. Prehosp Disaster Med., 2006; 21: 49-55.
21. Alarie Y. *Toxicity of fire smoke*. Crit Rev Toxicol., 2002; 32: 259-289.
22. <http://www.burnsurgery.org/Betaweb/Modules/initial/bsinitialsec11.htm> accessed January 2009.
23. Rosen and Barkin's *5-Minute Emergency Medicine Consult*. Lippincott Williams & Wilkins (LWW) Author(s): Peter Rosen, MD; Roger M. Barkin, MD; Stephen R. Hayden, MD; Jeffrey J. Schaidler, MD; and Richard Wolfe, MD; ISBN-10: 0781771722, ISBN-13: 9780781771726.

