Carbon Monoxide and Cyanide Poisoning Presentations and Oxygen Treatment

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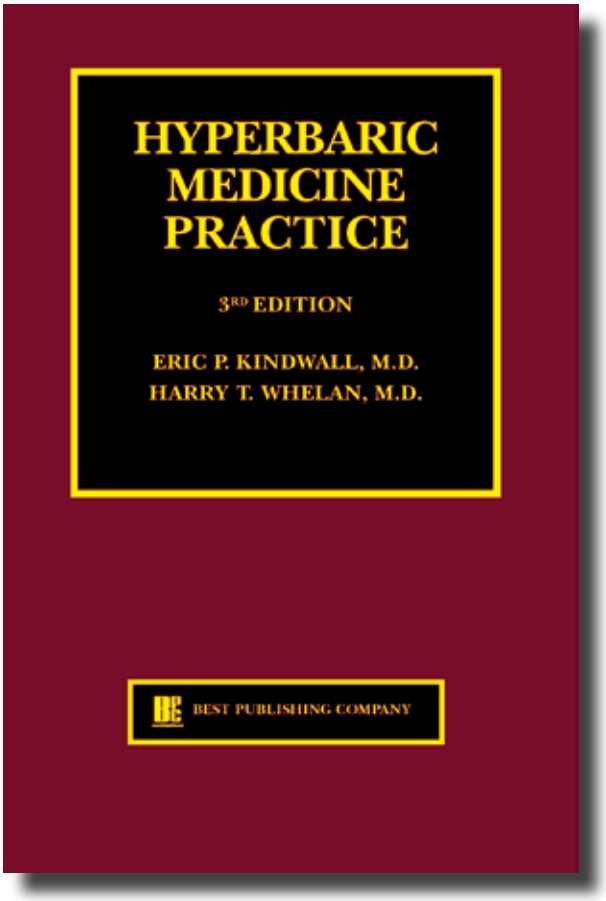

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CARBON MONOXIDE POISONING

Introduction

Carbon monoxide (CO) is one of the leading causes of injury and death by poisoning worldwide. Approximately 10,000 people in the United States per year seek medical attention for CO exposure and an average of 3,800 people die from CO poisoning: 1,500 due to accidents and the rest from suicide.[1-5] Because CO is colorless, odorless, tasteless, and nonirritating, its presence is difficult to detect. It is produced as a consequence of incomplete combustion of carbon-containing materials. The major source remains fire; therefore, CO presents an occupational hazard to fire fighters.[6] CO exposure from automobile exhaust is also common, the internal combustion engine accounts for 75% of all CO generated by pollution-generating human activities.[7] CO levels of more than 5% have been measured in nonsmokers exposed to engine exhaust on freeways.[8] Another major source of CO is cigarette smoking. Stewart et al. documented carboxyhemoglobin levels (COHb) above 9% in heavy cigarette smokers.[9] In the home and industrial settings, exhaust fumes also produce CO poisoning. Similarly, inadequate ventilation in conjunction with the use of fuels for home heating and cooking, such as wood, gas, and Sterno® blocks,[10,11] can elevate CO levels.

Other than a raised COHb level and a history of exposure, there are no truly specific findings from CO poisoning. Thus, it is a great mimic, with diverse and nonspecific clinical symptoms and signs.[12] As many as 30% of the victims of CO poisoning may be undiagnosed.[13] Therefore, to ensure good clinical outcome and reduce neurologic sequelae, clinicians must be well attuned to the various presentations of CO poisoning, and to the need for its early diagnosis and treatment. In marginal cases the index of suspicion must be high to make the diagnosis.

Clinical Presentations

Many factors impinge on the actual clinical presentation: the concentration of CO to which a patient is exposed, the duration of that exposure, the rate and depth of breathing, the heart rate, and, most important, the time between discovery of the patient after the exposure, and arrival at a hospital emergency department. Sayers and Davenport[14] described the classic symptomatology as follows: minimal symptoms were present at levels of COHb of less than 10%.; tightness across the forehead and headache were experienced at levels between 10% and 20%; levels of 20% to 30% resulted in a throbbing headache in the temporal regions; levels of 30% to 40% produced severe headache, generalized weakness, visual changes, dizziness, nausea and vomiting, and ultimate collapse. As the levels increased to 40% to 50%, syncope, tachycardia, and tachypnea occurred. Levels of over 50% were associated with coma and intermittent convulsions. Above 60%, death occurred due to cardiac depression and respiratory failure.

In our experience, and that reported by most investigators, the carboxyhemoglobin (COHb) level is only an indicator of exposure to CO; the level does not correlate well with

symptoms or with outcome.[15-19] Therefore, other tools are needed to prospectively evaluate the severity of CO poisoning. Because CO poisoning is known to be a great imitator of other illnesses,[12,20] including presenting as flu-like symptoms,[2,21] delays in the recognition and treatment of CO poisoning are frequent.

It is extremely rare to find the cherry red color that is classically described in CO poisoning. This sign represents a true soaking of the tissues with CO over a significant length of time. Thus it is a classical finding at autopsy, but contrary to popular belief, is not a clinical presentation. Any evidence of smoke or toxic-gas inhalation, and a history of exposure to a fire resulting in soot in the nasal or upper airways, singed nasal hair, and voice changes must be considered as an indicator of exposure to CO.

Neuropsychiatric Presentations

Neuropsychiatric manifestations of CO poisoning include non-focal alterations in mental status, seizures, amnesia, apraxia, agnosia, Parkinsonism, cortical blindness, incontinence, and peripheral neuropathy.[16] The first major follow-up evaluation of unconscious CO victims was by Smith and Brandon.[22] They documented, on a 3-year follow-up, a 33% personality deterioration, and a 43% memory impairment. These deficits were directly related to the level of consciousness on admission. A further eight patients showed gross neuropsychiatric damage. Central nervous system morbidity is most often subtle, and nearly always overlooked in the normal situation.[23] Recently, using another battery of tests, CO-poisoned patents were shown to have impaired context-aided memory, and to have improved function after hyperbaric oxygen therapy.[24]

Patients may appear to recover from acute CO poisoning, and then develop abnormalities from 1 to 21 days later.[25,26] Included in the presentation of the delayed syndrome may be aphasia, apraxia, apathy, disorientation, hallucinations, nuchal rigidity, gait disturbances, fecal and urinary incontinence, and bradykinesia. Cognitive and neurologic deficits may also be present, as can be personality changes with impulsiveness, violence, verbal aggressiveness, and mood changes. The reported incidence of this syndrome ranges from 3 to 47%.[15,22,26] The true incidence of delayed presentation may be higher, because personality and pathologic changes are often subtle and overlooked.[25]

Carbon Monoxide Poisoning in Children

Ninety percent of children presenting with CO poisoning have their exposure in the home.[27] Gastrointestinal disturbances (nausea, vomiting, and diarrhea) occur early and the COHb levels at presentation may be lower than those in the adult. The diagnosis is often overlooked or incorrect.[28] Lethargy and syncope are the most important symptoms in children.[27] The handling of a child in a hyperbaric environment may be complex, but the low complication rate enables us to conclude that there is no contraindication to treating children with CO poisoning with hyperbaric oxygen.

Patient Management

At the Scene

Today's pre-hospital care providers retrieving a person from a CO exposure would, in essence, clear the victim's airway, and then provide as high an oxygen concentration as they could with the available equipment, and commensurate with their level of training. The equipment may range from nasal prongs to facemasks to intubation and ventilation. The highest oxygen concentration possible can be achieved with endotracheal intubation, or with a reservoir oxygen bag in-line, with a tight fitting face mask firmly applied to the patient's face. The rigid plastic mask commonly used clinically in emergency rooms provides only 55 to 60% oxygen when flow is set on flood. A good "test" for tightness is to ask oneself if the patient could breathe from the mask lying on his back under water. An IV line is established to obtain a blood sample measurement of COHb, and to be able to administer drugs, should cardiac arrhythmias develop. All of the accepted advanced cardiac and trauma life support[29] protocols should be followed to ensure safe stabilized transport of the patient. Unconscious patients, or patients showing evidence of respiratory distress, should be intubated as early as possible. If intubation is done in the field, it is followed by ventilation with an Ambu or Laerdal bag until arrival at the hospital, where the patient would be switched to a ventilator.

Hospital Treatment

Unconscious patients need to be examined to exclude other causes of unconsciousness, and to identify associated injuries that might have been sustained in the traumatic event. It is essential to do a full work-up of the patient, as advocated in the Advanced Trauma Life Support course.[29] A detailed neurologic assessment must be undertaken. Patients who present with hypotension or arrhythmias may require fluid resuscitation and the use of lidocaine and dopamine. An EKG is most helpful in ruling out myocardial infarction; this is particularly important in patients with known coronary artery disease who are exposed to CO. Routine blood tests should be done, particularly for COHb levels, but also for the previously mentioned substances, such as agents measuring muscle breakdown.

The critical determination is the severity of the poisoning. In general, patients who should be observed in the emergency department or admitted to the hospital are those with the following problems:

1. COHb levels greater than or equal to 25%.
2. History of ischemic heart disease and COHb level greater than 15%.
3. COHb levels greater than 10% in a pregnant woman, leading to concern about the effects of CO on the fetus.
4. Ischemic chest pains and/or electrocardiographic evidence of ischemia.
5. Metabolic acidosis.
6. Abnormal psychometric testing.
7. History of unconsciousness.
8. Patients who remain symptomatic following 4 hours of 100% oxygen treatment.

9. Those patients arriving moderately symptomatic, but conscious, and with suspected CO poisoning at a hospital that lacks the ability to test COHb.

The majority of patients seen in emergency departments have a mild exposure to CO and become asymptomatic after receiving 100% oxygen for 3 to 4 hours. In this situation, the asymptomatic patient may then be sent home with the admonition to return should there be any recurrence of symptomatology within the next 7 to 10 days. In general, this type of patient may rapidly return to normal activity after a 24-hour layoff. It is also important to determine the source of CO in the home or industrial setting, and control it. Our policy has been to follow patients after discharge from the emergency department or hyperbaric chamber facility with a phone call between 7 and 10 days after the episode. The patients are also advised in writing that, if they have any symptoms, including neurologic deterioration, headaches, nausea, confusion, irritability, or personality change, they should contact us immediately for reassessment. We have noted that 12% to 23% of patients treated with surface oxygen develop delayed or recurrent sequelae between 1 and 21 days after their original exposure.[17,18]

Oxygen Treatment

The ultimate decision for the use of surface oxygen versus hyperbaric oxygen treatment should be based on neurologic presentation, rather than the COHb level alone. There is overwhelming evidence to support the use of hyperbaric oxygen in CO poisoning when there is a risk of mortality or morbidity. In terms of defining clear guidelines for referral for hyperbaric oxygen treatment, however, the major dilemma appears to be in establishing a threshold for poisoning severity below which clinical outcomes are not favorably affected by hyperbaric oxygen.[30] There is little doubt that patients should be referred for emergency treatment when they are comatose or have suffered an interval of unconsciousness. Some centers regularly prescribe hyperbaric oxygen therapy for patients with neurologic impairment documented by psychometric testing or other means of neuropsychological assessment; patients with COHb levels over 40%; patients who are pregnant and have COHb levels over 15% (assuming that the fetus is being treated); patients with a history of ischemic heart disease and a COHb level of 20% or above; patients who have been treated with surface oxygen and develop recurrent symptomatology up to 3 weeks after the original treatment, and patients whose symptoms do not resolve after 4 to 6 hours of continuous 100% oxygen. Separate from the question of hyperbaric therapy, serious consideration should be given to close monitoring of patients with cardiovascular involvement, including angina, ischemic ECG changes, cardiac arrhythmias, and a history of carbon monoxide exposure.

With the present-day advanced cardiac-life-support systems available for transportation, the hazards of transporting patients from a hospital without a hyperbaric

facility to one with a chamber have been reduced dramatically. It is understood that all necessary intervention will be done, and that the patient will be stabilized as much as possible prior to transportation. This includes airway management, IV line placement, infusion of medications and, when necessary, ventilators. It is essential that patients with cardiac arrhythmias, or previous cardiac arrest, will be stabilized first and then transferred at a later time, even though their carbon monoxide level has dropped. In severe poisonings it is both advantageous and safe to transport patients by helicopter for hyperbaric treatment.[31]

The ultimate decision to treat a patient with 100% oxygen at a local hospital, or to transfer that patient to a hyperbaric facility, will remain a difficult one to make. The community, transportation problems, available staff, and severity of symptoms must be considered. Each area should establish its own specific criteria, prior to a CO emergency, to determine which patients will be transferred.

Prognostic Factors

It is difficult to determine a prognosis for patients with mild to moderate exposure to CO poisoning, primarily because the COHb level is not a true indicator of severity of neurologic or cardiac involvement. For severely affected persons, poor prognostic indicators are prolonged coma; CT or magnetic resonance imaging abnormalities, particularly in the basal ganglion region;[32,33] and predisposing factors, such as heart disease and age. Until we are better able to do controlled comparative trials of various treatments, it will be difficult to predict outcomes. Long-term and severe psychiatric sequelae are also difficult to measure and compare. The writings describing these various conditions tend to be in earlier literature, that from the 1940s, 1950s, and 1960s, when the system for retrieval of patients from the scene and delivery to the hospital was radically different, and did not include oxygen as part of rescue resuscitation therapy. In today's world, there are rapid response times to fires and other emergencies, and early application of oxygen is a standard treatment modality. These interventions, though often life-saving, cloud the clinical presentation, affect the COHb level, and may alter the body's response to CO poisoning. The half-life of CO is rapidly reduced by higher oxygen concentrations; in 3 atmospheres of hyperbaric oxygen, the half-life is 23 minutes versus 320 minutes on air. However, there is great variation in the individual half-life, whether on air, 100% oxygen, or hyperbaric oxygen.[26,34,35]

CYANIDE POISONING AND TREATMENT

Cyanide produces an intracellular hypoxic poisoning due to the binding of cyanide anion to the ferric iron of mitochondrial cytochrome oxidase. Impaired oxidative phosphorylation results in the depletion of cellular high energy phosphate stores and lactic acidosis. The rapidity of cellular dysfunction and death are determined by the rate of entry of cyanide into the body. Thus, inhalation of a high concentration of hydrogen cyanide gas

(e.g., 270 ppm) is immediately fatal to man (whole blood cyanide levels of approximately 3.0 ug/ml). Ingestion of cyanide-containing salts are less rapidly fatal. At lower doses, cyanide may cause symptoms such as tachycardia and depression in the level of consciousness (e.g., whole blood cyanide levels of 0.5 to 2.5 ug per ml).[36]

Specific treatment of cyanide poisoning traditionally has been aimed at dissociating cyanide from cytochrome oxidase by instilling into the circulation an agent which has a higher affinity for cyanide than does the ferrous iron moiety of cytochrome oxidase. The Lilly Cyanide Antidote Kit is currently the only specific cyanide antidote available in the United States. Alternative antidotes to nitrite/thiosulfate are available in Europe. The motive for considering alternative therapies stems from the risk of nitrite toxicity. Too rapid administration can cause extreme vasodilatation and hypotension.[37] Excessive methemoglobin formation, rendering a large fraction of hemoglobin unable to carry oxygen, can be fatal.[38] Administration of a single therapeutic dose should produce a methemoglobin level of approximately 20%.[37] It is generally recommended that methemoglobin levels be maintained at less than 40%.[39]

Ventilation with an oxygen-enriched gas mixture significantly decreases cyanide toxicity. Oxygen administration at ambient pressure diminishes sensitivity to low doses of cyanide in animal and human experiments.[36,40] Paulet investigated the effect of oxygen on the sensitivity of anesthetized dogs infused with a dose of sodium cyanide just sufficient to produce apnea.[41] He found that even slight increases in oxygen partial pressure, to 1.03 ATA, improved respiratory function, compared with results with 1.0 ATA O_2, as well as the results with air. The slight excess oxygen pressure in this study was achieved with continuous positive airway pressure. Hyperbaric oxygen at 2.0 to 2.8 ATA decreases mortality from even high doses of cyanide in comparison with ambient pressure oxygen treatment.[42,43]

Compared with antidote treatment (nitrite/thiosulfate), oxygen treatment (100% at 1 ATA) by itself has no greater benefit, and often is less effective in maintaining aerobic metabolism and survival after cyanide poisoning. Combined nitrite/thiosulfate and oxygen treatments result in benefits significantly greater than when they are used individually.[44-47] Therefore, the practical consideration from these studies is that in the standard clinical setting, antidote therapy plus oxygen provides the greatest chance for therapeutic success. In the absence of antidote treatment, hyperbaric oxygen is of greater benefit than oxygen at 1 atmosphere pressure. While it seems reasonable that hyperbaric oxygen may have an even greater effect on survival versus ambient pressure oxygen, when combined with nitrite treatment, this was not found in a study by Way et al.[48] It is unclear, however, whether this observation may be related to the extraordinary oxygen pressure utilized (4 ATA for 2 hours). Experience with the current clinical recommendations for the use of hyperbaric oxygen, in cases refractory to standard management, is discussed elsewhere in this chapter.

COMBINED CARBON MONOXIDE AND CYANIDE EXPOSURE

Concurrent poisoning with carbon monoxide and cyanide is a relevant clinical problem in the treatment of patients suffering from smoke inhalation.[49-53] Carbon monoxide and cyanide have been shown to be synergistic in producing lethality in a mouse model,[54] which may explain a fraction of the mortality seen in smoke inhalation victims who die despite what might be considered sub-lethal carboxyhemoglobin levels.[52,55,56] Beyond the arguments for utilization of hyperbaric oxygen for CO or CN, described above, additional issues exist regarding combined poisonings. Central to the treatment of cyanide poisoning is formation of methemoglobin, which normally is not a major cardiovascular stress at levels of between 20 and 40%. However, when there is concurrent carboxyhemoglobin, the added functional anemia caused by methemoglobin formation may have a severe adverse effect. Hypoxia caused by methemoglobinemia can be ameliorated with hyperbaric oxygen.[57]

References

1. Centers for Disease Control. Mortality Morbidity Weekly Report. Carbon monoxide intoxication-A preventable environmental health hazard. 1982;31:529-31.
2. Dolan MC. Carbon monoxide poisoning. *CMAJ*. 1985;133(5):392-9.
3. Mofenson HC, Caraccio TR, Brody GM. Carbon monoxide poisoning. *Am J Emerg Med.* 1984;2:254-61.
4. Moolenaar RL, Etzel RA, Parrish RG. Unintentional deaths from carbon monoxide poisoning in New Mexico, 1980 to 1988. A comparison of medical examiner and national mortality data. *West J Med*. 1995;163(5):431-4.
5. U.S. Public Health Service: Vital Statistics of the United States, Washington, DC, Government Printing Office; 1976.
6. Sammons JH, Coleman RL. Firefighters' occupational exposure to carbon monoxide. *J Occup Med.* 1974;16(8):543-6.
7. Committee on Medical and Biologic Effects of Environmental Pollutants: Carbon Monoxide. National Research Council, National Academy of Sciences. Washington, D.C.; 1977. P. 28-37.
8. Aronow WS, Harris CN, Isbell MW, et al. Effect of freeway travel on angina pectoris. *Ann Intern Med.* 1972;77(5):669-76.
9. Stewart RD, Bartetta ED, Plate LR, et al. Carboxyhemoglobin levels in American blood donors. *JAMA*. 1974;229:1187-95.
10. Horvath SM, Dahms TE, O'Hanlon JF. Carbon monoxide and human vigilance. *Arch Environ Health.* 1971;23(5):3437.
11. Jackson DL, Menges H. Accidental carbon monoxide poisoning. *JAMA*. 1980;243:772.
12. Grace TW, Platt FW. Subacute carbon monoxide poisoning. Another great imitator. *JAMA*. 1981;246:1698-1700.
13. Barret L, Danel V, Faure J. Carbon monoxide poisoning, a diagnosis frequently overlooked. *Clin Toxicol.* 1985;23:309.
14. Sayers PR, Davenport SJ. Review of carbon monoxide poisoning. Public Health Bulletin 195. U.S. Government Printing Office, Washington, DC.; 1930.
15. Choi IS. Delayed neurologic sequelae in carbon monoxide intoxication. *Arch Neurol.* 1983;40(7):433-5.
16. Garland A, Pearce J. Neurological complications of carbon monoxide poisoning. *Q J Med.* 1967;36(144):445.
17. Myers RAM, Snyder SK, Emhoff TA. Subacute sequelae of carbon monoxide poisoning. *Ann Emerg Med.*

1985;14:1163-7.

18. Thom SR, Taber RL, Mendiguren II, Clark JM, Hardy KR, Fisher AB. Delayed neuropsychological sequelae following carbon monoxide poisoning and its prophylaxis by treatment with hyperbaric oxygen. *Ann Emerg Med*. 1995;25:474-80.
19. Winter PM, Miller JN. Carbon monoxide poisoning. *JAMA* 1976;236:1502-4.
20. Heckerling PS, Leikin JB, Maturen A. Occult carbon monoxide poisoning: validation of a prediction model. *Am J Med*. 1988;84:251-6.
21. Baker MD, Henretig FM, and Ludwig S. Carboxyhemoglobin levels in children with nonspecific flu-like symptoms. *J Pediat.* 1988;113:501-4.
22. Smith JS, Brandon S. Morbidity from acute carbon monoxide poisoning at three year follow up. *Br Med J.* 1973;1:318.
23. Jefferson J. Subtle neuropsychiatric sequelae of carbon monoxide intoxication: Two case reports. *Am J Psychiatry.* 1976;133(8);961.
24. McNulty JA, Maher BA, Chu M, Sitnikova T. Relationship of short-term verbal memory to the need for hyperbaric oxygen treatment after carbon monoxide poisoning. *Neuropsychiatry Neuropsychol Behav Neurol.* 1997;10:174-9.
25. Werner B, Beck W, Kerblom H, et al. Two cases of acute carbon monoxide poisoning with delayed neurological sequelae after a 'free' interval. *Clin Toxicol*. 1985;23:249.
26. Youngberg JT, Myers RAM. Use of hyperbaric oxygen in carbon monoxide, cyanide, and sulfide intoxication. In: Camporesi EM and Barker AC (eds.) *Hyperbaric Oxygen Therapy, A Critical Review.* Undersea and Hyperbaric Medical Society; 1991. P. 23-53.
27. Crocker PJ, Walker JS. Pediatric carbon monoxide poisoning. *J Emerg Med*. 1986;2:443.
28. Gemelli F, Cattani R. Carbon monoxide poisoning in childhood. *Br Med J.* 1985;26:291.
29. Advanced Trauma Life Support. Committee on Trauma of the American College of Surgeons. 1988.
30. Jakob A. Ober die diffuse hemispherenmarkerkrankung nach Kohlenoxydvergiftung bei fallen mit klinisch intervallerer Verlaufsform. *Zeitschrift For die Gesamte Neurologie und Psychiatrie*. 1939;167:161-4.
31. Lambrecht CJ, Mateer JR, Kindwall EP, Olson DW, Cisek JE,Stuven HA. Air Medical Transport for HBOT. *Travel Medicine International*. 1992;10:51-6.
32. Ikeda T, Kondo T, Mogami H, et al. Computerized tomography in cases of acute carbon monoxide poisoning. *Med J Osaka Univ*. 1978;29(3-4):253.
33. Sawada Y, Ohashi N, Maemura K, et al. Computerized tomography as an indication of long term outcome after acute carbon monoxide poisoning. *Lancet*. 1980;1:783.
34. Myers RAM. Do arterial blood gases have value in prognosis and treatment decisions in carbon monoxide poisoning? *Crit Care Med.* 1989;1720:139-42.
35. Myers RAM, Jones DW, Britten JS. Carbon monoxide half life study. In: Kindwall EP (ed.) Proceedings of the Eighth International Congress on Hyperbaric Medicine. Flagstaff: Best Publishing; 1987. P. 263-5.
36. Cope C, Abramowitz S. Respiratory responses to intravenous sodium cyanide, a function of the oxygen cyanide relationship. *Am Rev Respir Dis.* 1960;81:321-8.
37. Chen KK, Rose CL. Nitrite and thiosulfate therapy in cyanide poisoning. *JAMA*. 1952;149:113-9.
38. Berlin Jr. CM. The treatment of cyanide poisoning in children. *Pediatrics.* 1970;46:793-6.
39. Rumak BA. Cyanide poisoning. In: Newball, HH (ed.) Respiratory Care of Chemical Casualties. Proceedings of the Symposium on Respiratory Care of Chemical Casualties. US Army Medical Research and Development Command. McLean, VA; 1983.

40. Cope C. The importance of oxygen in the treatment of cyanide poisoning. *JAMA*. 1961;175:109-12.
41. Paulet G. Value and mechanisms of action of oxygen therapy in the treatment of hydrogen cyanide poisoning. *Arch Internat Physiol Biochim*. 1955;63:340-60.
42. Ivanov KP. Effect of increased oxygen pressure on animals poisoned with potassium cyanide. *Farmakol Toksik*. 1959;22:468-79.
43. Skene WG, Norman JN, Smith G. Effect of hyperbaric oxygen in cyanide poisoning. In: Brown I, Cox B (eds.) Proceedings of the Third International Congress on Hyperbaric Oxygen. Washington, DC, National Academy of Science, NRC; 1966. P. 705-10.
44. Burrous GE, Way JL. Cyanide intoxication in sheep: Therapeutic value of oxygen or cobalt. *Am J Vet Res*. 1977;38:223-7.
45. Isom GE, Way JL. Effect of oxygen on cyanide intoxication. VI. Reactivation of cyanide inhibited glucose metabolism. *J Pharmacol Exp Ther*. 1974;89:235-43.
46. Sheehy M, Way JL. Effect of oxygen on cyanide intoxication. III. Mithridate. *J Pharmacol Exp Ther*. 1968;161:163-8.
47. Way JL, Gibbon SL, Sheehy M. Effect of oxygen on cyanide intoxication. I. prophylactic protection. *J Pharmacol Exp Ther*. 1966;153:381-5.
48. Way JL, End E, Sheehy MH, Demiranda P, Feitknecht UF, Bachand R, Gibbon SL, Burrows GE. Effect of oxygen on cyanide intoxication. *Toxicol Appl Pharmacol*. 1972;22:415-21.
49. Birky MM, Clarke FB. Inhalation of toxic products from fires. *Bull NY Acad Med*. 1981;57:997-1013.
50. Hart GB, Strauss MB, Lennon PA, Whitcraft DD. Treatment of smoke inhalation by hyperbaric oxygen. *J Emerg Med*. 1985;3:211-5.
51. MacMillan V. Regional cerebral blood flow of the rat in acute carbon monoxide intoxication. *Can J Physiol Pharmacol*. 1975;53:644-50.
52. Mohler SR. Air crash survival: Injuries and evacuation toxic hazards. *Aviat Space Environ Med*. 1975;46:86-8.
53. Keenan HT, Bratton SL, Norkool DM, Brogan TV, Hampson NB. Delivery of hyperbaric oxygen therapy to critically ill, mechanically ventilated children. *J Crit Care*. 1998;13:7-12.
54. Norris JC, Moore SJ, Hume AS. Synergistic lethality induced by the combination of carbon monoxide and cyanide. *Toxicology*. 1986;40:121-9.
55. Anderson RA, Harland WA. Fire deaths in the Glasgow area III: The role of hydrogen cyanide. *Med Sci Law*. 1982;22:35-9.
56. Teige B, Lundevall J, Fleischen E. Carboxyhemoglobin concentrations in fire victims and in cases of fatal carbon monoxide poisoning. *Z Rechtsmed*. 1977;8:17-21.
57. Goldstein GM, Doull J. The use of hyperbaric oxygen in the treatment of p-aminopropiophenone-induced methemoglobinemia. *Toxicol Appl Pharmacol*. 1973;26:247-52.