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Review Article

Carbon Monoxide Toxicity and its Management: A Review

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I N F O

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A B S T R A C T

Carbon monoxide (CO) is emitted by incomplete ignition of carbonaceous substance. It is a tasteless, odorless and colorless gas, and victims are typically turned into comatose before they realize they are being poisoned. Clinical appearance in patients with CO poisoning starts from headache and dizziness to coma and death. The results of CO poisoning on humans are not always same, and healthcare professionals are just beginning to understand these effects better. CO is the most abundant toxin in the lower environment. Hyperbaric oxygen therapy can notablylessen the morbidity of CO poisoning, but a portion of survivors still suffer noteworthy long-term neurologic and affective squeals.

Keywords: CO Poisoning, Epidemiology, Fatalities, Studies and Management etc

Introduction

Many cases of CO exposure take place in private residences. CO is formed as a by-product of burning organic compounds. Most fatalities from CO toxicity result from fires, but stoves, portable heaters and automobile exhaust cause approximately one third of deaths. Cigarette smoke is a significant source of CO. Natural gas contains no CO, but improperly vented gas water heaters, kerosene space heaters, charcoal grills, hibachis, and Sterno stoves all emit CO. Fatality can arise during 1) Propane-fueled forklifts 2) Inhaling spray paint 3) Gas-powered concrete saws 4) Swimming behind a motorboat 5) Indoor tractor pulls etc. Carbon mono oxide intoxication also occurs by inhalation of a volatile liquid found in degreasers, solvents, and paint removers which are Methylene chloride vapors, Dermal Methylene chloride exposure may cause significant dermal burns. Methylene chloride is ingested, and can result in delayed CO toxicity. The liver metabolizes as much as one third of inhaled Methylene chloride to CO. A significant percentage of Methylene chloride is stored in the body tissues, and nonstop release results in elevated CO levels for at least twice as long as with direct CO inhalation.

Children riding in the back of enclosed pickup trucks seem to be at particularly high risk. Industrial workers at pulp mills, steel foundries, and plants producing formaldehyde or coke are at risk for exposure, as are personnel at fire scenes and individuals working indoors with combustion engines or combustible gases.

Pathophysiology

Carbon Monoxide enters the body through the lungs. Without the need for delivery of blood-borne hemoglobin direct interactions can damage the lung parenchyma. Elsewhere in the body, CO is evenly distributed by RBC in the body. it results in the leakage of capillary macromolecules from the lungs and systemic vasculature, and this may occur in human beings who have been exposed earlier with it to comparatively very low concentrations of CO for prolonged episode. As the level of carboxyhemoglobin (COHgb) go up, it dilates the cerebral blood vessels, and bothcapillary density and coronary blood flowrises up. Because of the persistence of exposure of CO, depression of central respiratory system develops which may result from Cardiac effects and cerebral hypoxia. Especially ventricular arrhythmias come about. Ventricular arrhythmias

are concerned as the cause of death most often in CO poisoning. There is evidence that the relatively low level of COHgb of 20% causes myocardial impairment. Generally causes the most animal's death poisoned by CO combined hypoxia and ischemia. It can direct changes the cellular activity linking immunological or inflammatory injury by a variety of mechanisms, includes 1) Binding with myoglobin, cytochrome a,a_3 2) Nitric oxide production leading to peroxynitrite generation 3) Neutrophils results Lipid per oxidation 4) Mitochondrial oxidative stress 5) Apoptosis 6) Immune-mediated injury 7) Delayed inflammation.

Various studies have proved that CO can result brain lipid per oxidation and leukocyte-mediated inflammatory alteration in the brain, this is a mechanism that may be inhibited by hyperbaric oxygen therapy. Because of severe intoxication, Central Nervous System (CNS) pathology exhibited by some patients, mainly white matter demyelination. Edema and focal areas of necrosis is common in such patients, usually of the bilateral globus pallidus. Interestingly, the pallidus lesions, and the other lesions, comes watershed area tissues having deficient of oxygen. Studies have confirmed the release of nitric oxide free radicals from platelet and vascular endothelium, following the coverage to CO concentrations of 100 ppm.

Epidemiology

It has seen in 40 cases of CO poisoning 80% of cases reported in winter month in closed area without ventilation. There is a 0.5 to 1.0/1,000,000 person fatality rate in America. CO may be accountable for 50% of all deadly poisonings. Its poisoning is the main contributing reason of death in fire victims. Almost 30% of CO-poisoning patient die before reaching for treatment. Of those hospitalized, approximately 2% die, 10% recover partially, and 23% to 47% suffer delayed neurologic sequelae.

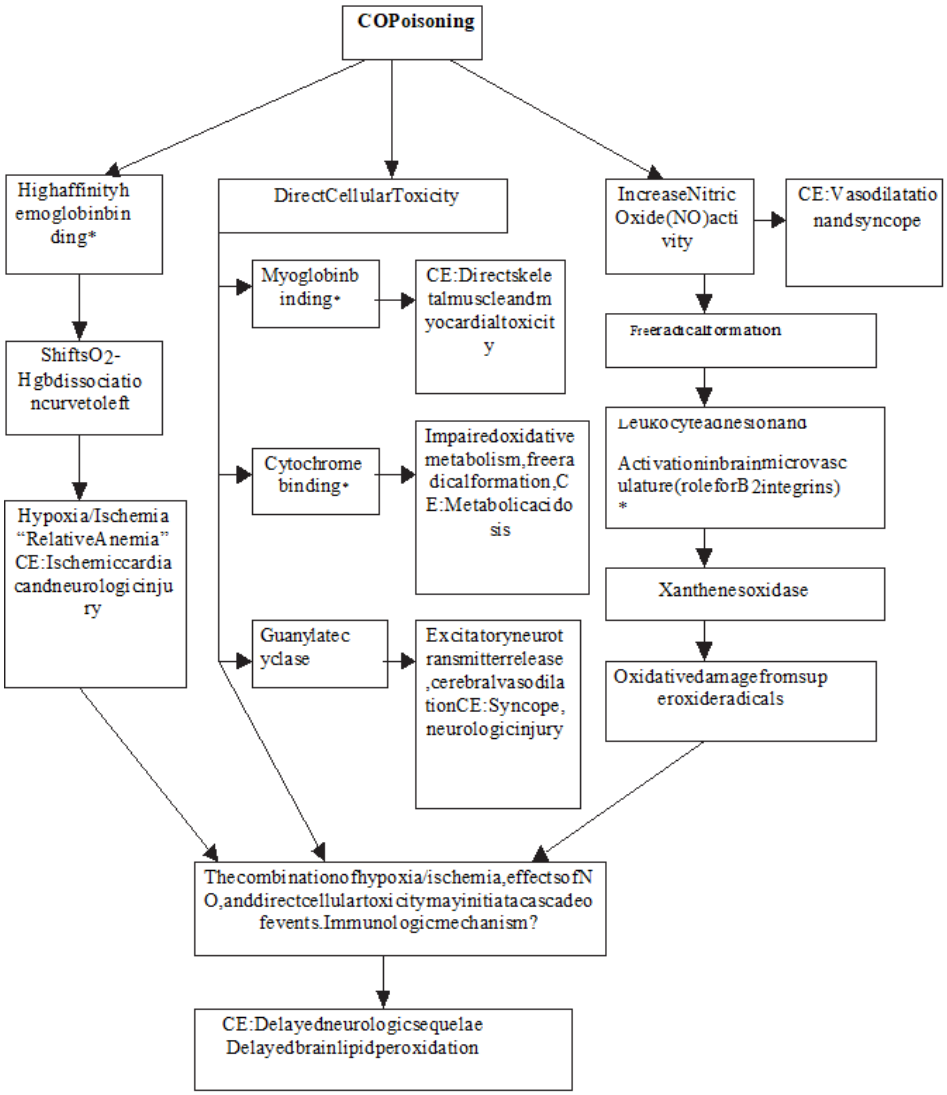

Figure 1.Proposed Pathophysiology of CO poisoning
*Potential hyperbaric oxygen therapy target. CE, clinical effect

History

The signs of CO poisoning can be such uneven that it can explains that only 5% to 6% of patients who admitted to the emergency department with CO poisoning receive HBOT. Most commonly the patients suffer with headache (more than 90%) weakness, dizziness and nausea. Tachycardia and tachypnea are the main symptoms of CO poisoned victims. Patient also suffers hypotension. Changed Mental status such as confusion, altered level of consciousness, disorientation and memory loss may take place. Intraocular deformities may include retinal hemorrhages, Papilledema with congestion. CO poisoning can cause renal dysfunction and ischemic injury. The classic indications, generally post-mortem findings indicate cherry red nail beds and mucous membranes. Ataxia, apraxia, incontinence, and cortical blindness are also some major symptoms of CO poisoning.

Imprecision and broad spectrum of complaints is the main reason of Misdiagnosis of carbon monoxide toxicity. symptoms often is characteristic by viral illness.

The most general symptom was headache (37%) in non lethal poisoning followed by dizziness (18%) and nausea (17%). However, any of the following symptoms should watchful suspicion in the winter season, especially when the patient has a history compatible with CO exposure or household presents with comparable complaints:1) Malaise, flulike symptoms, fatigue 2) Dyspnea on exertion 3) Chest palpitations 4) Lethargy 5) Confusion 6) Depression 7) Impulsiveness 8) Distractibility 9) Hallucination, confabulation 10) Agitation 11) Nausea, vomiting, diarrhea 12) Abdominal pain 13) Headache, drowsiness 14) Dizziness, weakness, confusion 15) Visual disturbance, syncope, seizure 16) Fecal and urinary incontinence 17) Memory and gait disturbances18) Bizarre neurologic symptoms, coma .Patient with constant CO exposure may present with loss of dentition, slow-onset neuropsychiatric symptoms, or, merely, recent impairment of cognitive capacity.

Physical

It should always alert the clinicians during treatment of any inhalation injury since there may be a great possibility of CO poisoning. Vital signs may include Tachycardia, Hypertension or hypotension, Hyperthermia and Marked tachypnea. Cherry-red skin has usually been considered a sign of CO poisoning ("When you're cherry red, you're dead") and Ophthalmologic findings include 1)Flame-shaped retinal hemorrhages 2) Bright red retinal veins 3) Papilledema 4) Homonymous hemianopsia 5) Noncardiogenic pulmonary edema Neuropsychiatric/or Neurologic findings may include.

- Memory disturbance (most common), as well as retrograde and intergraded amnesia with amnestic confabulatory states
- Expressive labiality, impaired decision and reduced cognitive ability
- unconsciousness, coma, gait disturbance, and movement disorders
- vigorous reflexes, apraxia , convulsion, psychosis, hearing and vestibular blindness, dysfunction,

Long-term experiences or severe acute contact often result in long-term neuropsychiatric sequelae. Furthermore, some victims develop delayed neuropsychiatric symptoms, often after severe intoxications connected with coma.

After improvement from the initial episode, patients present some days to weeks later with neuropsychiatric symptoms such as those just mentions. Two thirds of people ultimately recover completely.

Causes of Fatalities

- Mostly unintentional fatalities take place in immobile cars or buses from avoidable causes such as faulty exhaust outlets in an improperly ventilated passenger compartments.
- Automobile-related CO deaths in garages are more commonly have occurred in compare to open garage windows or doors,
- Both for firefighters and victims in the setting of structure fires, Oxygen deprivation cause greater risk than thermal injury as more CO is evolved in the surrounding.
- cooking or heating is mainly done with unvented cook stoves, wood, charcoal, animal dung, or agricultural waste in most of the developing nations, which has been connected purely with elevated HbCO levels
-]Boats and houseboats signify a important and underappreciated source of exposure, with numerous case history and studies·

Diagnoses being performed for detection of CO Poisoning

- Acute Lactic Acidosis
- Acute Respiratory Distress Syndrome
- Alcohol Toxicity
- Depression and Suicide
- Diabetic Ketoacidosis (DKA)
- Emergent Treatment of Gastroenteritis
- Encephalitis
- Hypothyroidism and Myxedema Coma
- Labyrinthitis
- Meningitis
- Methemoglobinemia
- Migraine Headache
- Opioid Toxicity
- Pediatrics, Hypoglycemia
- Tension Headache

Laboratory Studies

An elevated level of carboxyhemoglobin (HbCO) The clinical diagnosis of acute carbon monoxide (CO) poisoning should be confirmed by demonstrating. Either arterial or venous blood can be used for testing. Analysis of HbCO requires direct spectrophotometric measurement. It provides the perfect result in specific blood gas analyzers. Bedside pulse carbon monoxide (CO)-oximetry is also in great use for this purpose. A 2012 study showed that non persistent pulse CO-oximetrycompares with more fastanalysis and initiation of hyperbaric oxygen therapy than laboratory CO-oximetry.

High CO levels of 10% in smokers and at least 3% - 4% nonsmokersare considerable. If the patient already has received 100% oxygen or if significant time has intervened since exposure low levels do not rule out exposure of HbCO but may be as high as 10% in some heavy smokers. Arterial blood gas measurement findings include:

- Value of partial Pressure of Oxygen (PaO_2) levels should always stay standard; saturation of oxygen is exact only if measured directly but not if calculated from PaO_2, which is same in many blood gas analyzers.
- Estimation of total PCO_2 is done by subtracting the total amount of carboxyhemoglobin from the saturation of PCO_2 levels in pulse oximetry. From ischemia, metabolic acidosis take place secondary to lactic acidosis.
- The ACEP advocates obtaining an electrocardiogram and cardiac biomarker levels in emergency division patients with modest to severe CO toxicity. Cardiac marker results include the following:
- Raised high-sensitive troponins I value often indicate cardiomyopathy, as well as reversible worldwide dysfunction and a Takotsubo-like fashion.
- Myocardial ischemia is common in victims hospitalized for moderate-to-severe CO exposure and is a interpreter of mortality.
- Victims with pre existing cardiovascular illness can experience enhanced degree of angina with HbCO levels of just 5-10%; at high levels of HbCO, even immature healthy people can cause myocardial infarction.

Other test results include the following

- Severe CO toxicity even can Result acute renal failure, Creatinine kinase, urine myoglobin - Nontraumatic rhabdomyolysis
- Impacts on Electrolytes and glucose level - Hypokalemia and hyperglycemia occur with severe intoxication with CO.
- Rise of blood lactate level is a warning sign of severity, and may associate with neurologic outcomes. If CO is emitted from fire and the lactate level is 10 mmol/L or higher, the patient may have suffering from cyanide poisoning.
- Myoglobinuria causes acute kidney failure.
- Mild elevation in fulminant hepatic failure indicated in liver function tests
- During chronic intoxication Urine analysis for albumin and glucose show Positive.
- In Methemoglobin level shows normal PaO_2 but differential diagnosis of cyanosis with low oxygen saturation.
- Instances of suicide attempt have been noticed in Toxicology screening.
- A confounding factor of both intentional and unintentional poisonings has been seen in when Ethanol level tested.
- Cyanide level - during industrial fire cyanide toxicity also is being suspected; unexplained metabolic acidosis in cyanide exposure is suggested;
- The most common cause of acute cyanide poisoning is Smoke inhalation

Imaging Studies

With significant intoxications, chest radiograph in patients are obtained. If, hyperbaric oxygen is to be used pulmonary symptoms or evidence of hypoxia are being check up carefully. Though results usually are not abnormal. Changes such as the following applied a worse prediction than normal results:

- Ground-glass appearance
- Perihilar haze
- Peribronchial cuffing
- Intra-alveolar edema

Computed Tomography

Obtaining the CT scanning of the head with severe intoxication or alteration in mental condition that does not resolve quickly. Evaluate focal lesions and cerebral edema; nearly all typically low-density lesions of the basal

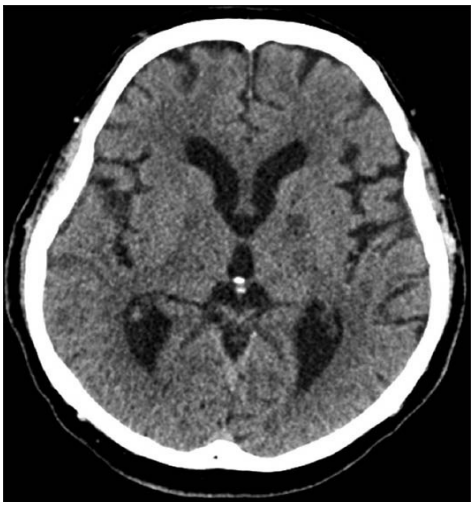

Figure 2.Bilateral Globus Pallidus Lesions Seen on CT of the Brain after CO Poisoning

Ganglia Neurologic complications are predicted on positive result of CT scan. In one experiment, 53% victims hospitalized for acute CO poisoning had not normal CT scan findings; every patient was suffering neurologic sequelae. The patient with negative result in CT scan were only 11% had also neurologic sequelae.

Magnetic Resonance Imaging

For uncovering the focal lesions and white matter demyelination MRI is more accurate than CT scans and is often used for transcribed care. The succession from conventional MRI to diffusion-weighted imaging (DWI) and then diffusion tensor imaging (DTI) has made progressively more sensive estimation of damage from CO toxicity. DTI can picture progressive pathologic transformation in the early phase of CO poisoning,

Other Tests

Sinus tachycardia is the slightest abnormality detected in electrocardiography; Arrhythmias comes next to hypoxia, ischemia, or infarction. Severe impact on patients has been noticed mainly on cardiovascular system on very low rise of HbCO.

Neuropsychologic Testing

Formal Neuropsychologic testing of concentration, even in mildly poisoned patients, the motor function, and problem solving consistently reveal slight shortage. In almost 30 minutes by a compliant examiner a shortened versions of these tests can make available that can be performed. For emergency department (ED) setting these are more appropriate.

Study point towards a precise link to deficits in context-aided memory in CO toxicity. Employing such specific testing in the ED has been suggested very early as a tool for determining the severity of neurologic participation.

Prehospital Care

Pre hospital care includes

- Promptly eliminate the patient from prolonged contact and immediately introduce oxygen therapy with a non re breather mask.
- Carry out intubation for the comatose victim or, if needed for airway protection, and make available 100% oxygen treatment.
- Organize cardiac monitoring. Pulse oximetry, through its not helpful in detecting carboxyhemoglobin (HbCO), is still significant because a low saturation causes even bigger apprehension in this set.
- Provide information to the emergency department for comatose or unsteady patients because fast or direct relocate to a hyperbaric center may be indicated.
- In possibility obtain ambient carbon monoxide (CO) amounts from fire department or utility company personnel, when present.
- Samples of early blood may provide much more exact association between HbCO and technical status; however, there mustn't delay oxygen administration to obtain them.
- Acquire an estimate of exposure time, if possible.
- Avoid application to limit tissue oxygen demand.

Emergency Department Care

Considerations in Emergency Department (ED) care include:

- **Cardiac Monitoring:** Sudden death has taken place in victims with severe disease such as arteriosclerotic at HbCO levels of only 20% exposoure.
- **Pulse Oximetry:** HbCO absorbs light almost of the same amount to that of oxyhemoglobin. Although a linear fall in oxyhemoglobin occurs as HbCO level goes up, pulse oximetry will never reflect this. Either one measure saturation directly or by pulse oximetry the difference in value between the both always is same to the HbCO level. Oxygen therapy is generally supplied via a non-re breather mask. However, Roth et al describe efficient use of noninvasive continuous positive airway pressure (CPAP) ventilation using a tight mask and an inspired fraction of oxygen (Fi_{O2}) of 100%. These authors present case reports of concurrent CO toxicity in a couple, in which levels fell from in the patient treated with CPAP shows falling the level of HbCO 21% at admission to 6% within 1 hour and 3% after 90 minutes. In the spouse, who was treated with usual oxygen therapy, decrease of HbCO from the admission level of 21% to 3% took 6 hours.
- Until the patient is asymptomatic and HbCO levels are below 10% it is recommended to Continue 100% oxygen therapy. Lower thresholds of 2% have been advised in patients with cardiovascular or pulmonary compromise.
- Using the initial level and half-life of 30-90 minutes at 100% oxygen

Evaluate a gross estimate of the essential duration of treatment

- Venous HbCO levels and oxygen therapy are probable sufficient in unsophisticated intoxications. Evaluate patient's initial HbCO levels above 15% for myocardial ischemia and infarction with significant cardiovascular disease and Consider instant transfer of patients with rise above 40% or neurologic or cardiovascular impairment to a hyperbaric facility. Hyperbaric treatment at lower carboxyhemoglobin levels (above 15%) is recommended for Pregnant patients.
- Funduscopy, CT scans, and, possibly, MRI, are important in detecting the development of cerebral edema for

that Sequential neurologic assessment must be done time to time. Cerebral edema needs intracranial pressure (ICP) and invasive blood pressure checking to further guide therapy.

- Acidosis generally recovers with oxygen remedy. That's why never treat acidosis with a pH above 7.15 aggressively, because it causes a rightward shift in the oxyhemoglobin dissociation curve, rising tissue oxygen availability.
- Consider some other poisonous inhalants or thermal inhalation injury as contributing factors in victims who fail to recover clinically. It must be kept in mind that nitrites used in cyanide kits cause methemoglobinemia, which can shift the dissociation curve leftward and further hindering oxygen liberation at the tissue level. Mixed toxicity of CO and cyanide may be treated with sodium thiosulfate 12.5 g intravenously to avoid shifting the curve leftward.
- If HbCO levels show 30-40% or above 25% with related symptoms. Admit the victim to monitored setting and estimate the acid-base status

Hyperbaric Oxygen Therapy

Hyperbaric Oxygen (HBO) therapy is at present rests at the center of controversy surrounding management of CO intoxication. Increased removal of HbCO clearly takes place. Various experiments declared major decrease in delayed neurologic sequelae, cerebral edema, decreased cytochrome oxidase impairment and pathologic central nervous system (CNS) alteration. Currently, universal treatment criteria do not exist; though, a study of directors of North American HBO facilities with 85% responding reveals some consensus. The general assortment criteria (regardless of HbCO level) comprise the following:

- Coma (98%)
- Transient loss of consciousness (77%)
- Ischemic ECG changes (91%)
- Focal neurologic deficits (94%)
- Abnormal neuropsychiatric test results (91%).

Complications

Survivors of CO intoxication are at threat for an array of neurologic and psychiatric complications, including:

- Impaired intellectual function
- Short-term memory loss
- Dementia
- Amnesia
- Psychosis
- Irritability
- Dysfunctional gait
- Speech disorders
- Parkinson disease
- Cortical blindness
- Depression

** Among various complications, suicide is the greater risk for Survivors of CO poisoning.

Further Outpatient Care

Patients with HbCO levels below than 10% may be discharged. Patients should be followed up in 4-6 weeks to screen for cognitive sequelae in cases of accidental CO intoxication, while psychiatric follow-up is compulsory withdeliberate poisoning, since incidents given the high rate of subsequent completed suicide.

Further Inpatient Care

- For more severe cases admitted patients are generally

Concentration	Symptoms
35 ppm (0.0035%), (0.035‰)	Headache and dizziness within six to eight hours of constant exposure
100 ppm (0.01%), (0.1‰)	Slight headache in two to three hours
200 ppm (0.02%), (0.2‰)	Slight headache within two to three hours; loss of judgment
400 ppm (0.04%), (0.4‰)	Frontal headache within one to two hours
800 ppm (0.08%), (0.8‰)	Dizziness, nausea, and convulsions within 45 min; insensible within 2 hours
1,600 ppm (0.16%), (1.6‰)	Headache, increased heart rate, dizziness, and nausea within 20 min; death in less than 2 hours
3,200 ppm (0.32%), (3.2‰)	Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes.
6,400 ppm (0.64%), (6.4‰)	Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes.
12,800 ppm (1.28%), (12.8‰)	Unconsciousness after 2–3 breaths. Death in less than three minutes.

provided monitored settings, telemetry beds, or cardiac care unit/medical intensive care unit (CCU/MICU) beds. Patients suffering from cerebral edema must be most suitably treated in a neurosurgical ICU setting. It may be helpful to consult any toxicologists for the service in such, cases.

Prognosis

Considerations regarding prognosis include:

- Inconsistency of clinical severity, laboratory values, and result limits provide accuracy in prognostic.
- Abnormal CT or MRI findings are linked with constant neurologic impairment.
- Neuropsychiatric testing may have predictive effectiveness in identifying delayed sequelae

Patient Education

- Carbon monoxide (CO) detectors: Patients should be much educated on the importance of home CO detector alarms. In market such devices are available with audible alarms
- Patient must discuss the likelihood of delayed neurologic complications, although they are usual in victims with toxicity severe enough to necessitate hospital admission under experienced doctors
- Recommend to mitigate physical movement for 2-4 weeks
- Counsel patients if they smoke cigarette
- For such education information, visit the First Aid and Injuries Center, as well as Carbon Monoxide Poisoning

Effects of carbon monoxide in relation to the concentration in parts per million in the air.

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