REVIEW

Carbon monoxide poisoning: undetected by both patients and their doctors

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Abstract

Carbon monoxide poisoning represents a potentially preventable and reversible cause of mortality and morbidity if sources and cases can be identified. The elderly have been shown to be particularly at risk. Concerns continue to be raised about potential unrecognised cases of carbon monoxide poisoning. These concerns arise from difficulties in knowing who to suspect as a potential victim of poisoning as well as how, when and what to test. In general carbon monoxide has no helpful unique clinical presentation and is known to mimic common illnesses as well as exacerbate established diseases. As a gas it is undetectable by the human senses and is potentially present in most households. This paper reviews the issues associated with carbon monoxide poisoning including pointers to early diagnosis and discussion of pathophysiology and management.

Keywords: carbon monoxide poisoning, aged, guidelines, elderly, carbon, monoxide, poisoning, diagnosis

Introduction

Carbon monoxide (CO) gas is recognised to cause 50 deaths a year and 200 sub-lethal poisonings [1, 2]. There is great concern that these figures are greater. An editorial in the British Medical Journal, noted that every year some 250,000 gas appliances are condemned and if only a proportion of these were emitting CO it can be estimated that the number of poisonings could be much greater than currently detected [1].

Carbon monoxide is undetectable to the human senses, being colourless, odourless and tasteless. Being produced by the incomplete combustion of carbon-based products, such as gas or coal, it has the potential to be present in the majority of households. The diagnosis is generally only suspected in cases of high-level acute intoxication, such as with deliberate self-harm or after a house fire. The spectrum of poisoning can vary from acute high level to chronic lower level such as with a faulty heater when duration of use, time spent exposed and ventilation will affect toxicity. CO poisoning mimics common conditions such as ‘flu and gastroenteritis and produces isolated non-specific symptoms such as fatigue or headache. The symptoms of low level, chronic CO intoxication are non-specific and unlikely to arouse suspicion of CO as the cause. It can also represent a contributory factor in exacerbating known disease, such as ischaemic heart disease or dementia.

Studies published looking at wider testing generally reveal that there are a small but significant number of cases that would have remained undiagnosed. One trial looking at screening homes in the USA following emergency calls found a high CO level in 3.4% of homes, with 35% of inhabitants having some of the symptoms potentially attributable to CO toxicity [3]. Other studies have tried to target those patients at higher risk, with sensitivity and specificity of approximately 75% [4]. A number of reports look at the increase in the number of cases of CO poisoning presenting after a major storm [5, 6]. A retrospective epidemiological study from the Midlands showed that cases were more prevalent in the winter months and that the very young and the very old were at the highest risk [7]. Two abstracts from southern England, looking at elderly patients admitted over the winter, showed 12 out of 314 had abnormally high carboxyhaemoglobin levels (over 2%), and that in three of these a cause was identified [8, 9]. Over the winter, this equates to at least one patient each week for most hospitals with acute medical takes.

The Chief Medical Officer wrote to all doctors advocating more screening and greater awareness of the problem [10]. However, the described difficulties remain of who to suspect and how to diagnose CO poisoning. This article outlines the important aspects of carbon monoxide and its poisoning, as well as aiming to provide the medical practitioner with practical guidance to help reach the Chief Medical Officer’s objective of greater knowledge and awareness of carbon monoxide poisoning and its detection.
Sources of carbon monoxide

The problem stems from a defective device, poor ventilation or poor evacuation of combustion gases (see Table 1). The most common exposure sites were the kitchen and bathroom, with 68% occurring in the home. The water heater and central heating accounted for over half the cases in one study from Spain. The fuels most commonly implicated were butane, propane and natural gas [11].

Other reports include people suffering CO poisoning in the absence of fossil fuels, such as from an electric storage heater that was shown to have significant loss of carbon from damaged areas [12]. Other reports implicate car exhausts that have been blocked by snow [13] and swimming behind a boat [14]. Laser coagulation has also been shown to increase carboxyhaemoglobin levels [15]. The elderly have less physiological reserve and are more likely to have other conditions to account for their symptoms, and so the condition may not be suspected or investigated. Also, they are more likely to be housebound, and thus more susceptible to carbon monoxide build up if there were poor ventilation.

Detection of a faulty appliance can be a major problem as the emission of CO can be variable, for example, with changes in the wind or birds resting on chimneys. All rented accommodation must have its gas appliances checked annually for faults, though there are no compulsory guidelines for private homes. Average carbon monoxide levels in home without gas stoves are typically 0.5–5 p.p.m., while homes with properly adjusted gas stoves have levels around the cooker 5–15 p.p.m. Poorly adjusted stoves may give rise to levels of over 30 p.p.m. [16]. The risks associated with car exhausts have reduced since wider use of catalytic converters, which reduce carbon monoxide emissions from approximately 3.5% to 0.5% [17], and carbon monoxide emissions fell by 42% between 1990 and 2000 [18].

Pathophysiology

The main effects of carbon monoxide are thought to be through hypoxia (see Table 2). Carbon monoxide has an affinity for haemoglobin over 200 times that of oxygen as it forms carboxyhaemoglobin. It induces structural changes to the haemoglobin molecule, favouring a more stable binding to oxygen on the other haem groups, and further reducing the release of oxygen to the tissues. With the tissues becoming hypoxic, the patient’s respiratory drive is stimulated, and unless the environment has changed, this results in increased CO levels.

The affinity of carbon monoxide for fetal haemoglobin and for myoglobin is higher still. The former is important because pregnant mothers with even very minor CO poisoning need to be treated very carefully, as the effects on the fetus are disproportionate to those of the mother. The CO binding to myoglobin, to form carboxymyoglobin (COMb), both in the heart and skeletal muscles, is felt to be important in the association of CO toxicity and ischaemic heart disease (coupled with the heart’s high oxygen demands). It has also been implicated in the delayed effects of CO toxicity and ‘rebound’ phenomena, whereby patients show more symptoms as treatment progresses. This is thought to be through the release of CO from myoglobin with a subsequent rise in COHb [19].

Other theories on the mechanism of the effects of CO include its binding to cytochrome a3 and its role as an endogenous inflammatory mediator. Much of the tissue damage involves inflammatory changes and white cell activation, with increased capillary leakage and oedema [20]. CO has also been shown to impair tissue perfusion through myocardial depression and arrhythmias and peripheral vasodilatation [21]. Indeed, prognosis in acute poisoning correlates more closely with the degree of hypotension than the degree of hypoxia [22].

Other problems are seen with reperfusion injury on treatment causing increased oxidative stress and free radical formation [23]. In particular, lipid peroxidation and the formation of xanthine oxidase are felt to be important in the underlying mechanisms leading to damage.

The half-life of carboxyhaemoglobin is variable, with a mean of 320 minutes (128–409 minutes) in young healthy volunteers breathing room air. Giving 100% oxygen at 1 atmosphere reduces this to 80 minutes, which further falls to 23 minutes at 3 atmospheres [24].

Presenting features

The presenting features of carbon monoxide poisoning are extremely vague. They include general malaise, headache and flu-like symptoms or gastroenteritis (see Table 3). It has also been shown to exacerbate pre-existing diseases, such as

<table>
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<tr>
<th>Table 1. Sources of carbon monoxide</th>
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<tbody>
<tr>
<td>Car exhausts</td>
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<tr>
<td>Central heating systems</td>
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<td>Methylene chloride based paint stripper</td>
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<td>Open fires or barbecues</td>
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<td>Tobacco smoke</td>
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<th>Table 2. Possible mechanisms for the effects of carbon monoxide</th>
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<tr>
<td>Binding to haemoglobin</td>
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<tr>
<td>• Reduces overall O2 carrying capacity</td>
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<tr>
<td>• Competitive with O2</td>
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<td>• Structural change further reducing O2 dissociation</td>
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<tr>
<td>• Hyperventilation causes respiratory alkalosis that further reduces O2 dissociation at the tissues</td>
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<tr>
<td>• Increased affinity for HbF than HbA</td>
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<tr>
<td>Binding to myoglobin</td>
</tr>
<tr>
<td>• Reduces tissue O2 supply</td>
</tr>
<tr>
<td>• Delayed symptomatology</td>
</tr>
<tr>
<td>• Heart myoglobin with 3 times greater affinity than skeletal myoglobin</td>
</tr>
<tr>
<td>Binding to cytochrome a3</td>
</tr>
<tr>
<td>• No clear evidence of clinical significance as yet</td>
</tr>
<tr>
<td>Ischaemia</td>
</tr>
<tr>
<td>• Cardiac depression and arrhythmias</td>
</tr>
<tr>
<td>• Peripheral vasodilatation and hypotension</td>
</tr>
<tr>
<td>Reperfusion injury</td>
</tr>
<tr>
<td>• Oxygen free radicals causing lipid peroxidation</td>
</tr>
<tr>
<td>• Probably mediated through leucocytes</td>
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<td>Its role as an inflammatory mediator</td>
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Table 3. Some clinical features of carbon monoxide poisoning

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<tr>
<td>Headache 90%</td>
<td>Rhabdomyolysis</td>
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<tr>
<td>Nausea and vomiting 50%</td>
<td>Diabetes insipidis</td>
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<td>Lethargy 30%</td>
<td>Parkinsonism and other movement disorders</td>
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<tr>
<td>Altered conscious level 30%</td>
<td>Implicated in a case of post-partum haemorrhage</td>
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<td>Subjective weakness 20%</td>
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<tr>
<td>Also</td>
<td>Arhythmias</td>
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<tr>
<td>Pulmonary oedema</td>
<td>Hypotension</td>
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<tr>
<td>Coma</td>
<td>Exacerbation of existing disease</td>
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<tr>
<td>Confusion</td>
<td></td>
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<tr>
<td>Depression</td>
<td></td>
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<td>Ataxia</td>
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<td>Hearing problems</td>
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angina or COPD [25]. In the elderly where there are often multiple different problems, there may appear to be even less reason to look for a further cause, despite this group being at high risk. The classical cherry red appearance is not seen in all cases of acute poisoning, and may not be apparent even in cases of severe toxicity [26]. One retrospective study of CO poisoning showed that the initial diagnosis was stroke in three, seizure in one, encephalitis in two and ischaemic heart disease (IHD) in four (n = 40). Neurological and respiratory signs and symptoms were noted in 19 and 18 of 25 patients, respectively [27].

There is only limited correlation between the COHb level and severity of clinical features, and cases have been reported of severe toxicity at only low levels of poisoning [28].

Immediate death is most likely to be due to a lethal arrhythmia [29], due to cardiac sensitivity to hypoxia and the preferential binding to cardiac myoglobin. Severe poisoning is often complicated by hypotension and pulmonary oedema, with the former being the most reliable marker for overall prognosis in severe cases [22].

A common late complication of CO poisoning is with the development of delayed neuropsychiatric impairment. This usually presents between 2–28 days after poisoning, with behavioural changes, ataxia and poor memory [29]. It does not generally resolve completely, even after treatment for the initial poisoning. Cerebellar dysfunction at presentation has been found to be a predictor for cognitive sequelae [30].

Suspicion arousers

The features that may lead to suspicion of CO poisoning are when more than one household member is affected. Also, there may be a history of non-specific illness in any pets, whose smaller bodies are more susceptible to poisoning. The majority of poisonings occur in winter, when there is increased use of fossil fuels for heating and ventilation is minimised to conserve heat. Symptoms may be better after a break away from home, or worse at weekends when patients spend longer in the home. They may be worse after cooking, most commonly noted in the evenings after supper. With gas heating, a yellow flame that leaves black sooty marks on the surrounds is suggestive of incomplete combustion. As opposed to the clearer blue flame. Smoke may accumulate, and while CO itself is odourless, other gases in the smoke may be apparent.

Making the diagnosis

The diagnosis is normally made by measuring the percentage of carboxyhaemoglobin in either arterial or venous blood samples. There is excellent correlation between the two, as would be expected for a stable compound such as COHb [31]. Oxygen saturation measurements are known to be unreliable and overestimate the levels [32]. Devices that measure exhaled carbon monoxide levels have been shown to correlate well with blood levels. However, these have been evaluated in otherwise healthy patients (typically in smoking cessation clinics) and their reliability in the acutely ill patient has not been assessed [33, 34].

There are changes found on neuroimaging that correlate with overall prognosis [35]. The areas of the brain that are the most sensitive to the effects of CO poisoning include the globus pallidus and other basal ganglia, the white matter and the cerebral cortex.

Treatment

The most obvious part of this is removing the patients and others away from the source. A significant amount of recovery is to be expected from patients receiving 100% oxygen and appropriate cardiovascular support. Patients often require ITU.

The most contentious part of this is the role for hyperbaric oxygen (HBO), which involves the risks inherent in transferring critically ill patients and barotrauma. HBO therapy is most effective within 6 hours of poisoning [36]. The rationale behind using hyperbaric oxygen includes [37]:

i. A reduction in the half-life of COHb from 320 minutes to 80 minutes with 100% oxygen and then down to 22 minutes at 3 atmospheres.
ii. Induction of cerebral vasoconstriction with reduced intracranial pressure and cerebral oedema.
iii. Increases CO dissociation from cytochromes and myoglobin.
iv. HBO may reduce oxidative injury following CO poisoning.

The results of randomised controlled trials have shown mixed results, though were generally in favour of its use [38–40], though one trial showed a trend towards a worse outcome in the HBO group [41]. Trials have shown a reduction in neuropsychological disability in mild to moderate cases of CO poisoning who would otherwise not receive this treatment [38]. A recent Cochrane review of the use of hyperbaric oxygen concluded that at present the evidence...
did not support the use of HBO, but acknowledged that the knowledge base was inadequate and advised further adequately powered trials [42]. A double-blind, randomised controlled trial looking at acute carbon monoxide poisoning, not available for inclusion in the Cochrane review, showed an improvement in outcome for patients treated with HBO. The majority of patients had COHb levels of over 10%. There was a reduction in cognitive sequelae from 46.1% in those treated with normobaric oxygen to 25% in those treated with hyperbaric oxygen. There remain many questions as to which patients will benefit most and how to give the HBO.

The current recommendations from the CMO are that hyperbaric oxygen should be considered in patients with a COHb of >20% and 1 or more of the following [10]:

i. Loss of consciousness at any stage.
ii. Neurological features other than headache.
iii. Myocardial ischaemia/arrhythmia.
iv. Pregnant patients.

Mixtures of oxygen and carbon dioxide have also been investigated for pre-hospital treatment with favourable results [42].

Prognosis

It has been estimated that there is an approximately 30% mortality for severe poisoning, while 11% of survivors have persistent functional deficits and 3% develop delayed neuropsychiatric sequelae impairments, such as poor memory or behavioural changes [43]. There is also concern for those with chronic exposure that the effects may persist after the patient has been removed from the source [20]. Those with the worst prognosis include those with the highest COHb levels, those with reduced conscious level, the elderly and those with pre-existing cardiovascular disease, metabolic acidosis and those with structural changes on neuroimaging [43, 44]. As previously stated, the degree of hypotension has been shown to be the best guide to prognosis [22].

Implications of CMO advice on clinical practice/recommendations for screening within the NHS

The implications of the CMO’s letter are that we should be testing COHb levels far more than we currently do, which has significant resource implications. The cost of the blood tests for screening can vary between £0.70 and £6.00 in different hospitals. Breath-testers can be used which require little training and are relatively cheap. They require the patient to hold their breath for 15 seconds prior to exhaling into the machine. They are not appropriate in patients who are vomiting, short of breath or too confused to use them, and have only a limited role for hospital doctors. Screening homes opportunistically on home visits by occupational therapists would be one approach, and ambulance personnel have checked levels in trials from the States. More targeted screening has been tried, though would still miss a significant number of cases.

Prevention of poisoning

Regular servicing of gas appliances and ensuring adequate ventilation are obviously very important. Carbon monoxide testers are available for the home, with both visual and audible alarms, and which are reasonably cheap. The detectors vary in their sensitivity to carbon monoxide, with some only adequate to detect relatively high levels of ambient carbon monoxide, and so would not protect against chronic low-level poisoning.

Further information

- Local CORGI (Council for Registered Gas Engineers) engineer.
- Local Environment Health Department.
- Health and Safety Executive Helpline (0800 300 363).
- National Poisons Information Service Centre.

Key points

- Carbon monoxide poisoning is a treatable condition that is underdetected by doctors and associated with significant morbidity.
- The condition is more common in winter, and should be suspected when more than one household member is affected.
- Symptoms and signs are non-specific (e.g. general malaise, headache, increased confusion, ‘gastroenteritis’) and should be considered in patients presenting with vague, prolonged or recurrent symptomatology.
- Carbon monoxide poisoning should be considered as a potential precipitant for chronic diseases (e.g. COPD, IHD).
- There is poor correlation between the COHb level and severity of clinical features, with hypotension being the best predictor of outcome.

References


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