



## PRACTICE

## EASILY MISSED?

## Carbon monoxide poisoning

James Ashcroft *academic foundation programme doctor*<sup>1 2</sup>, Emma Fraser *fire, water and carbon monoxide safety and senior development officer*<sup>3</sup>, Sanjay Krishnamoorthy *consultant in acute medicine*<sup>2</sup>, Sue Westwood-Ruttledge *patient adviser and campaigner for carbon monoxide poisoning awareness*<sup>4</sup>

<sup>1</sup>Department of Surgery and Cancer, St Mary's Hospital, London, UK; <sup>2</sup>Department of Acute Medicine, West Middlesex University Hospital, Isleworth, UK; <sup>3</sup>London Fire Brigade, London, UK; <sup>4</sup>Sale, Cheshire, UK

## What you need to know

- Carbon monoxide (CO) poisoning can present in patients as a wide range of acute and chronic symptoms
- Diagnosing CO poisoning relies on taking a thorough history exploring the relationship of symptoms to environment
- Emission of abnormally high CO levels can be detected by certified carbon monoxide alarms and can be avoided by routine maintenance of fuel burning appliances

*A 23 year old man with no medical history presents to the emergency department with a three day history of headache, transient visual disturbance, dizziness, and hypertension. On clinical examination the patient is flushed and drowsy with redness in the sclera, with no further visual or systemic symptoms. A venous blood gas on air shows a carboxyhaemoglobin level (COHb) grossly elevated at 26.0 (0-3), which leads to the diagnosis of carbon monoxide poisoning.*

## What is carbon monoxide poisoning?

Carbon monoxide (CO) is a poisonous gas produced through burning fuel. Sources of CO in the home include boilers and central heating systems, cookers and barbecues, and fireplaces and chimneys (figure).<sup>1</sup> Owners of such appliances are required to have them serviced by registered technicians as per recommended individual guidance (usually once per year).<sup>1</sup> If outlets from these appliances (such as flues and chimneys) become blocked or if they are operated as normal in a closed environment with no ventilation, dangerous levels of CO can build up in living spaces.<sup>1</sup> When inhaled in high quantities, CO enters the bloodstream and binds to haemoglobin molecules with a much greater affinity (230 times higher) than oxygen, creating carboxyhaemoglobin.<sup>2</sup> The binding of CO results in reduced delivery of oxygen to tissues, which leads to tissue ischaemia.<sup>2</sup>

## Why is it missed?

Presentation of CO poisoning is not frequent enough for the condition to be prioritised in medical training, diagnostic decision making, initial patient testing, and publicity and public awareness.<sup>3</sup> Differential diagnoses include common acute presentations such as viral flu, gastroenteritis, tension and migraine type headaches, and alcohol toxicity, and making a diagnosis is therefore difficult.<sup>1</sup> Determining the severity of symptoms can be challenging as symptoms may fluctuate within hours, lessening when leaving and worsening when returning to the source of CO.<sup>1</sup> Furthermore, there is no established correlation between carboxyhaemoglobin levels found on blood gas analysis, making quantification of CO poisoning difficult. An increased tolerance to CO is commonly found in cigarette smokers, making this cohort of patients particularly difficult to assess, as symptoms may only appear after a substantial exposure to CO.<sup>1 4 5</sup>

The greatest concern regarding missed CO poisoning diagnoses is the impact on the cardiovascular and neurological systems. A study recruiting 104 sequential patients with unstable angina to a coronary unit in Pietà, Malta, found that eight had previously undetected evidence of CO poisoning.<sup>6</sup> The same group of researchers undertook screening of all 307 admissions to an acute neurological unit and found in 29 people presenting with impaired consciousness and no further signs, that three had evidence of CO poisoning.<sup>7</sup> In Chicago, two patients out of 43 presenting with epileptic seizure had evidence of CO poisoning.<sup>8</sup> Individual cases of missed CO poisoning have also been described. The R Adams Cowley Shock Trauma Center, Baltimore, reported eight cases of chronic exposure from three weeks to three years, where patients presented with non-specific physical pain, shortness of breath, sleep disturbance and

nightmares, weight loss, tinnitus, muscular spasm, photophobia, ataxia, paranoia, and memory loss.<sup>9</sup>

## Why does this matter?

According to the Office for National Statistics and the Carbon Monoxide and Gas Safety Society, approximately 50 people die from CO poisoning each year in the UK.<sup>10,11</sup> Between 1995 and 2017, there were 676 UK deaths caused by accidental CO poisoning.<sup>10</sup> Near misses from unintentional CO poisoning came to 5542, and of those, 2250 required hospital treatment.<sup>12</sup> CO poisoning is a persistent international cause for concern and may be intensified in less economically developed countries.<sup>13,14</sup>

## Presentation

Symptoms of acute and chronic CO poisoning are summarised in the [table](#).

Acute CO poisoning commonly presents with a tension type headache, dizziness, nausea, and vomiting.<sup>1</sup> These symptoms may make patients believe they have contracted food poisoning or flu, delaying presentation.<sup>1</sup> Patients may have recently travelled or spent time away from the source of CO, leaving windows and doors shut and allowing CO to accumulate, which on return can bring acute and severe symptoms. Severe weather conditions may also lead to the use of indoor heat generator systems without ventilation, which increases the risk of toxic CO accumulation.<sup>1</sup>

Those who have been exposed to open fires are at risk of both CO poisoning and cyanide toxicity, caused by combustion of hydrogen containing natural and synthetic materials.<sup>15</sup>

### A case of missed carbon monoxide poisoning

Sue Westwood-Ruttledge, a patient author for this article, was poisoned by carbon monoxide over three years caused by a disconnected appliance duct in her newly built house.

Sue says, "After moving to a new house I had many episodes of feeling generally unwell with lethargy, headaches, dizziness, and nausea. I also struggled to concentrate. I put my symptoms down to being run down due to working long hours. Several times when I had been away on holiday and the windows had all been closed I would come home, go to bed, and be violently sick all night long. My son who was 6 years old when we moved into the house suffered from frequent stomach pains and headaches. After taking him to the GP, each time I was told he was fine and it was suggested my son was trying to get out of going to school."

Sue's diagnosis came with difficulty. She underwent a range of neurological examinations, blood investigations, and imaging studies including computed tomography and echocardiography. One of the leading differentials for Sue's case was cocaine abuse, which was distressing for her and left her feeling abandoned.

Following multiple hospital admissions, a routine boiler service by a registered technician revealed a carbon monoxide leak which ultimately led to her diagnosis.

Chronic CO poisoning may not present with severe symptoms and may be present in the form of mild tiredness, confusion, stomach pains, or shortness of breath.<sup>1</sup> This may further develop to a broad range of neurological symptoms including dementia-like memory changes, parkinsonism, and emotional changes, sleep disturbance, chronic pain syndromes, and fatigue.<sup>1</sup> The time to onset for acute CO poisoning is directly related to the concentration of CO the patient is exposed to, as is the severity of chronic CO poisoning.<sup>1</sup> A typical timeframe of acute CO poisoning presentation is hours following exposure, while patients with chronic CO poisoning present with symptoms ranging from weeks to months in duration.<sup>1</sup> Because of the short to moderate half life of CO and the day-to-day activities of patients requiring them to leave the CO source, blood levels of CO often do not accumulate to life threatening levels for a long period. Chronic CO poisoning can therefore go

undiagnosed until a chance prolonged exposure to the CO source ultimately allows blood levels to accumulate beyond a symptomatic threshold, leading to an acute presentation.<sup>1</sup> Acute CO poisoning may be caused by a high flow CO leak from a faulty fuel burning appliance within the same room as the patient's living space.<sup>1</sup> Chronic CO poisoning may be caused by a smaller dose of CO escaping from the source or a larger distance between the patient and source, eg, a next door neighbour's faulty fuel burning appliance.<sup>1</sup>

## Clinical examination

Diagnosis of CO poisoning requires a thorough history taking to link any clinical symptoms to environment and exposure to CO. Cardiovascular examination with electrocardiogram may reveal a sinus tachycardia, however CO poisoning has also been associated with angina and cardiac ischaemia.<sup>6,8</sup> Neurological examination may reveal non-specific symptoms, such as a broad spectrum of sensory changes, inattention, memory change, confusion, ataxia, and in severe cases seizure and reduced consciousness.<sup>6-8</sup> Carboxyhaemoglobin is brighter in hue than oxyhaemoglobin, which is the cause of the red conjunctival injection in the case in this article.<sup>9</sup> Textbooks often report elevated carboxyhaemoglobin levels that lead to a "cherry red" skin tone, however this appears to be unfounded and exceptionally rare.<sup>16</sup> Signs on clinical examination of CO poisoning have a poor predictive value, making the key to diagnosis the connection of onset/worsening of symptoms to CO exposure.

### Clinical features of acute CO poisoning<sup>7-9</sup>

#### Symptoms

- Headache
- Dizziness
- Nausea and vomiting

#### Examination

- Diagnosis is largely made on clinical symptoms and history/exposure to CO
- Neurological examination may reveal non-specific signs, dizziness, and confusion

#### Investigation

- Electrocardiogram
- Lactate levels
- Carboxyhaemoglobin (COHb) level measurements through venous blood gas

#### Findings

- Hypotension
- Tachycardia, rarely arrhythmias or cardiac ischaemia
- Lactate may be elevated in severe CO poisoning
- Raised carboxyhaemoglobin (COHb) levels, with toxic effects appearing at 15-20%

## Initial tests

Pulse oximetry, which relies on absorption of infrared light by haemoglobin, is often falsely high in CO poisoning because of the similar properties of oxyhaemoglobin and carboxyhaemoglobin.<sup>15</sup> A venous or arterial blood gas analysis is required for the measurement of carboxyhaemoglobin for definitive diagnosis, and this is rarely available outside the hospital environment.<sup>5</sup> CO levels should be lower than 3% in non-smokers, but have been found to be as high as 15% in heavy smokers.<sup>5</sup> The accumulation of carboxyhaemoglobin to a level

of 15-20% is considered to give the toxic effects of CO poisoning.<sup>7-9</sup>

A novel method of detecting CO levels is the use of breath analysis, allowing non-invasive quantification of exhaled CO level in an attempt to detect poisoning.<sup>17,18</sup> Whereas carboxyhaemoglobin levels show a linear relationship with clinical severity in CO poisoning, breath analysis has failed to show the same result and should not be used to exclude early CO poisoning.<sup>17,18</sup>

## Management

Refer patients with suspected CO poisoning to the emergency department for investigation and further management.<sup>15</sup> Only severe cases of CO poisoning require admission, and most identified acute presentations are treated and discharged to a place of safety.<sup>19</sup> Treatment includes driving CO out of the body and tissues, and using oxygenation to encourage the association of oxygen with haemoglobin.<sup>1</sup> Deliver 100% high flow oxygen to the patient through a non-rebreather mask as early as possible in the community or at the emergency department.<sup>19</sup> This reduces the half life of carboxyhaemoglobin from 4 to 6 hours to 40-80 minutes, therefore enabling treatment of the acute presentation within hours.<sup>19</sup> Treatment should take effect immediately, but can vary depending on patient and dose of CO.<sup>7</sup> All patients presenting acutely are recommended to have a minimum six hours of oxygen therapy.<sup>7</sup>

### How to prioritise CO poisoning as a differential diagnosis

- Patients describing neurological symptoms such as dizziness, loss of balance, vision and memory disturbances, loss of consciousness or collapse, lack of concentration, and unusual emotional and mood changes over a long period in conjunction with flu like symptoms should prompt investigation into CO poisoning<sup>1</sup>
- Ask about potential sources of CO and changes in environment or exposure to fuel burning appliances coinciding with symptoms. If there is an exposure risk, CO poisoning must be explored
- An initial predictor model (detecting 45 cases from 61 patients tested) suggests that in patients presenting with any CO poisoning symptoms and affected cohabitants (including pets), a CO poisoning diagnosis should be prioritised and investigated<sup>23</sup>

### Advice on what to do in a suspected CO leak

- Open all doors and windows to ventilate the building if immediately possible
- If it is safe to do so, switch off all CO producing appliances
- Get outside into the fresh air quickly
- If someone is showing signs of poisoning or has collapsed, get them outside, call 999, and ask for an ambulance
- Seek immediate medical advice. Go to hospital and on arrival inform staff that you suspect CO poisoning
- Before returning home, call the gas emergency number on 0800 111 999 (UK) and tell them what has happened

Recovery is measured by complete elimination of symptoms as opposed to a normal CO value.<sup>19</sup> Limited evidence suggests that hyperbaric oxygen results in better long term outcomes and reduced complications following CO poisoning.<sup>20</sup> A meta-analysis of six randomised controlled trials found no statistically significant benefit in treating CO poisoning with hyperbaric treatment when compared with normobaric treatment with regard to a range of immediate and delayed neurological sequelae.<sup>21</sup> Specialist advice is required for patients presenting with a carboxyhaemoglobin level of greater than 25%, pregnancy, or substantial neurological or cardiovascular symptoms.<sup>3,20</sup> For patients treated for chronic carbon monoxide

poisoning, manage any lasting effects conservatively with long term follow-up if necessary.<sup>7</sup>

The London Fire Brigade advises members of the public to buy a CO detector for all rooms that contain a fuel burning appliance.<sup>22</sup> CO detectors sound a loud alarm if a harmful level of CO gas is reached within an area.<sup>22</sup> It is the only method to detect CO gas within the household, enabling safe evacuation and preventing harmful CO effects.<sup>22</sup> Detectors should be installed in an open unobstructed area of wall or ceiling at a metre's distance from the appliance.<sup>22</sup> Ultimately, public and medical awareness, timely detection, and efforts towards prevention of CO poisoning are key to reducing morbidity and mortality from this serious condition.

### How patients were involved in the creation of this article

The case description in this article is based on a patient who was treated in the emergency department. Sue Westwood-Ruttledge, whose life has been personally affected by carbon monoxide poisoning, contributed to the shape of the article and described her experiences in the Patient Perspective box "A case of missed carbon monoxide poisoning."

### Education into practice

- What are the different presentations for which you might consider carbon monoxide poisoning as a differential diagnosis?
- How will this article help you consider both the acute and chronic effects of carbon monoxide poisoning?
- What will you do differently in your practice after reading this article?

**Contributors** JA devised the article. SW-R, EF, and SK gave intellectual contribution. SW-R advised the article as a patient adviser. JA created the article draft, which was revised by SK, EF, and SW-R.

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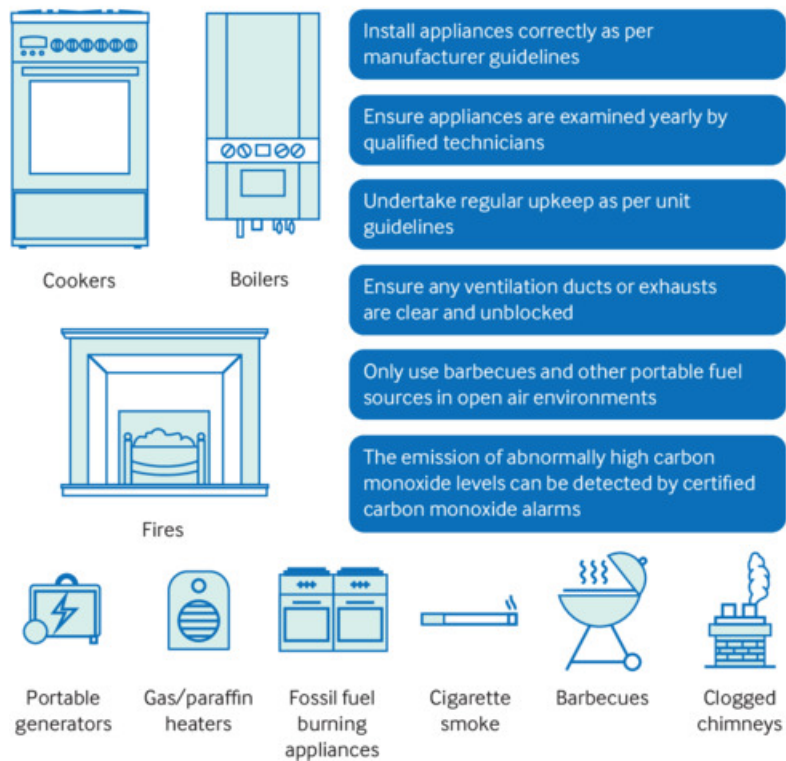
## Table

Table 1 | Acute vs chronic CO poisoning

Acute	Chronic
Headache	Inattention, memory loss, and fatigue
Tiredness	Sleep disturbance
Abdominal aching	Personality and mood changes
Nausea and vomiting	Parkinsonism, ataxia, and seizure syndromes
Chest pain or generalised pain	Muscular spasms
Shortness of breath	Tinnitus
Seizure	Photophobia
Coma	Chronic pain syndromes
Death	Cardiac ischaemia

# Figure

## COMMON SOURCES OF CARBON MONOXIDE



**Figure** Common domestic sources of CO