Case reports

Lessons from practice

Carbon monoxide-induced death and toxicity from charcoal briquettes

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Clinical record

During July 2009, a 42-year-old man and another person cooked a barbecue lunch on the verandah of a small apartment in Sydney, using charcoal briquettes as the cooking fuel. At the end of the barbecue, the tray containing the still burning charcoal was transferred into the apartment as a source of heat. The apartment was beneath the flight path of a nearby airport and had noise insulation that reduced inflow of fresh air. A day and a half later, after concerns had been expressed by family and friends, police officers and landlord representatives entered the apartment to find the man deceased. The other person was unconscious, and was treated by paramedics and transferred to the emergency department of a nearby hospital.

At autopsy, the man was found to have inhaled sufficient carbon monoxide (CO) to cause death (his blood concentration of CO was 61%). The presence of postmortem lividity indicated that he had probably died a few hours after the burning briquettes were placed in the apartment. An inquest held in the State Coroner's Court of New South Wales found that the cause of death was accidental CO poisoning after exposure to fumes from barbecue briquettes burned indoors.[1] A possible factor in the man's death was the presence of significant, but undiagnosed, coronary artery disease, which is likely to make a person more susceptible to the toxicity of CO.[1]

The other person had inhaled sufficient CO to cause loss of consciousness. Owing to the position in which this person had collapsed, the prolonged period of unconsciousness led to compression of the right arm with secondary ischaemia, compartment syndrome and rhabdomyolysis in the right arm. A below-elbow amputation was performed 9 days after the incident, and subsequent recovery included some residual hypoxic sequelae. ◆

This case highlights the problem of burning charcoal briquettes in a poorly ventilated space, which can generate toxic carbon monoxide (CO) concentrations.[1] CO is a colourless, odourless and non-irritating gas with no warning properties. Sources of CO are related to incomplete combustion of carbon-containing materials under conditions of restricted oxygen supply, and include faulty furnaces, unflued heaters, compressors, wood-burning stoves, vehicle exhaust, welders, other petrol- or diesel-fuelled equipment, and building fires.

The mechanism of CO toxicity is asphyxiation through inhibition of oxygen binding to haemoglobin, where CO has an affinity for the haemoglobin oxygen binding sites of over 200 times that for oxygen. CO also raises cellular haem concentrations, which interrupts cellular respiration, and causes oxidative stress and inflammation via multiple pathways.[2]

For mild, short-term exposure (below about 500 parts per million [ppm]), symptoms can include headache, dizziness, nausea, impaired psychomotor function (and also some abnormal behavioural function), loss of balance, fatigue and respiratory symptoms.[3] As the concentration increases, these symptoms intensify. Lethal concentrations are relatively low — death occurs after about 2 hours at 1500 ppm, and can occur after shorter exposures at higher concentrations (eg, within 30 minutes at 3000–6000 ppm).[2,4]

Death by suicide using non-vehicular CO is well documented,[5,6] and charcoal barbecues and hibachis have previously been associated with unintentional deaths.[7-9]

Stoichiometrically, it is possible to estimate the quantity of briquettes that need to be burned to produce a potentially toxic concentration of CO in an apartment with a defined volume.

The weight (W) of a gas, in grams, in 1 m^3 at 100% concentration is:

W g = molecular weight of the gas ÷ standard molar volume × 1000

The weight of CO in 1 m^3 at 100% concentration is:

$W\ g = 28.01 \div 22.47 \times 1000$

$= 1247\ g$

The weight of a gas, in grams, in 1 m^3 at a concentration of c, where c is the concentration as a percentage, is:

$W_c\ g = W\ g \times c \div 100$

The weight of CO in 1 m^3 at 1% concentration (10 000 ppm) is:

$W_1\ g = (28.01 \div 22.47) \times 1 \div 100$

$= 12.47\ g$

The weight of CO at 1% concentration in an apartment is dependent on the volume of the apartment, ignoring walls, furniture, other objects and people, so it is:

$W_{apartment} = W_1\ g \times$ volume of the apartment

The weight of CO at 1% concentration in an apartment of 100 m^3 volume is:

$W_{apartment} = 12.47\ g \times 100$

$= 1247\ g$

The proportion of a CO molecule that is carbon is 43%, so the weight of carbon in an apartment containing 1% CO is:

$W\ carbon = W_{apartment} \times$ proportion of CO that is carbon

$= 1247\ g \times 0.43$

$= 535\ g$

Lessons from practice

- Under circumstances of incomplete combustion and poorly ventilated spaces, charcoal briquettes can generate toxic concentrations of carbon monoxide (CO).
- The amount of charcoal briquettes required to produce toxic concentrations of CO is quite small — about the amount normally used in conventional barbecues.
- In cases of CO poisoning, the role of other health conditions, perhaps even undiagnosed conditions (eg, coronary disease, heart failure, obstructive lung disease), may be significant factors in the development and outcome of toxicity or death. ◆

Finally, the proportion of carbon in the charcoal briquettes used in this incident, as stated in manufacturer information, is 85%. Therefore, the weight of briquettes needed to produce 1% CO in a 100 m^3 apartment is:

W briquettes = W carbon ÷ proportion of briquette that is carbon

= 535 g ÷ 0.85

= 629 g

In summary, if the concentration of carbon in the briquettes is 85%, the lethal concentration of CO is 10 000 ppm and the volume of an apartment is 100 m^3, then burning 629 g of charcoal briquettes could produce a potentially toxic atmosphere. Therefore, using a typical amount of briquettes of about 1 kg in a poorly ventilated area is likely to lead to clinical toxicity and might lead to death.

This case highlights the problem of burning combustion sources in a poorly ventilated space, and shows that quite small amounts of charcoal briquettes can, once burning, produce toxic or lethal amounts of CO.

In summing up, the coroner recommended that a warning be placed on all charcoal briquettes sold in Australia:

> The burning of BBQ charcoal can give off carbon monoxide, which has no odour, and can be lethal. NEVER BURN CHARCOAL INDOORS OR IN VEHICLES OR TENTS. When burning BBQ charcoal, ensure BBQ area is well VENTILATED. Keep out of reach of children. Please take care when burning.[1]

Competing interests: I received consulting fees for preparing a report for and providing expert testimony to the State Coroner's Court of New South Wales for the case that is the subject of this article.

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