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Carbon monoxide concentrations in the 2009 Victorian Bushfire disaster victims☆

Dimitri Gerostamoulos [a,b,*], Jochen Beyer [a,b], Katherine Wong [a], Catherine Wort [a], Olaf H. Drummer [a,b]

[a] Victorian Institute of Forensic Medicine, Monash University, Kavanagh Street, Southbank 3006, Australia
[b] Department of Forensic Medicine, Monash University, Kavanagh Street, Southbank 3006, Australia

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ABSTRACT

Blood was available for the estimation of carboxyhemoglobin saturation (COHb) in 30 of the 173 persons who died in the Victorian bushfires in February 2009. The ages of these 30 deaths ranged from 3 to 80 years and there were 8 females. 13 cases (43%) were considered negative (less than 5% COHb), 12 (40%) were between 5 and 40% COHb, 2 (6.7%) between 40 and 50% and 3 (10%) were greater than 50% COHb. There were 6 persons either found within a building or a car and the COHb in these cases ranged up to 69% (mean 50%). There were 5 cases where the location was unable to be determined as either indoor or outdoor due to the extensive nature of the fire. The remaining 19 deceased persons were all located outside in the open and the concentration of COHb in these cases ranged up to 30% (mean 19%). Hydrogen cyanide was only detected in two deceased persons at concentrations of 0.5 and 2.7 mg/L, respectively. 13 deceased were found to have soot in the airways following necropsy but this did not correlate with the COHb levels.

1. Introduction

Carbon monoxide (CO) is a colorless, odorless gas that is poisonous to humans. CO inhalation through the lungs results in the formation of carboxyhaemoglobin (COHb), which impairs the oxygen carrying capacity of the blood. CO can be produced naturally or by human activity. Cigarette smokers often have low tolerable levels of COHb (up to 10%). In otherwise healthy individuals, concentrations of COHb at levels of 20–30% can lead to headaches, dizziness and shortness of breath; whereas levels of 30–50% can lead to confusion, unconsciousness; and levels in excess of 50% are usually life threatening [1].

Combustion of timber, houses and other materials can lead to a variety of poisonous gases which can be inhaled by people in fire areas. Flash fires can result in significant amounts of carbon monoxide being liberated into the atmosphere [1]. While the majority of deaths involving CO poisoning occur in house fires, literature reporting of CO in deaths in forest fires is less common. The sources of CO in this bushfire are likely to be numerous given the natural environment. The human contribution (houses, cars, and sheds) is also likely to be a significant source of CO, as well as of other poisonous gases (including hydrogen cyanide).

Victoria suffered a great natural disaster on Saturday 7 February 2009 with 173 persons being killed in the devastating fires [2]. The temperature in Melbourne reached 46.4 °C (116 °F) with winds up to 100 km/h. The major fires occurred in 14 different geographical regions and burnt an area of over 350,000 ha [2]. There were 414 patients who presented to hospital emergency departments around Victoria as a result of the bushfires.

Toxicological analysis in victims of fire is usually limited and in a disaster of this kind, as it is arguable that the cause of death (effects of fire) in the vast majority of cases is already established. Limited toxicology was performed to see if there was evidence that the person was alive at the time of the fire or whether smoke inhalation, as measured by COHb levels, may have caused or contributed to death.

This paper aims to determine the prevalence of CO in deaths from the Victorian bushfires and in those cases where death was attributable to CO poisoning, to establish the concentration range of blood carboxyhaemoglobin saturations and to investigate whether there was any correlation between the COHb levels, soot in the airways and the circumstances of death.

2. Methods

The Victorian Institute of Forensic Medicine (VIFM) is a purpose built facility situated in Melbourne, Australia, serving a population of some 5 million people and providing a medicolegal death

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* Corresponding author at: Victorian Institute of Forensic Medicine, Monash University, 57-83 Kavanagh Street, Southbank 3006, Australia.
Tel.: +61 3 9684 4347; fax: +61 3 9682 7353.
E-mail address: dimitrig@vifm.org (D. Gerostamoulos).

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Table 1
Demographics, blood carboxyhemoglobin saturation and hydrogen cyanide concentrations.

Case	Sex/age	State of body	[COHb] %	[HCN] mg/L	Pathological assessment of soot deposit in airways	Soot	Location found
1	F > 21	Severely burnt	12	0	No sooting mentioned, severely burnt body	NA	Outside
2	M > 21	Intact	15	0	Possible thermal injury to the mucosa of the trachea and bronchi	N	Outside
3	M > 21	Intact (lower part only)	16	0	Examination of the proximal trachea disclosed soot within the lumen	Y	Outside
4	F > 15	Intact	21	0	Not mentioned in report	NA	Not specified
5	F < 15	Intact	24	0	Extensive charring of the upper part of the torso including chest and upper abdomen. There is an abundant amount of soot staining on the teeth, nasal passages and trachea.	Y	Outside
6	M > 21	Intact	26	0	Internal examination showed a moderate amount of soot within the proximal one-third of the trachea	Y	Outside
7	M > 21	Intact	29	0	Evidence of soot deposition around the mouth and nose and also on the tongue and within the trachea	Y	Not specified
8	M > 21	Severely burnt	30	0	Opening the trachea along its posterior boundary demonstrates extensive soot deposition within deep trachea and bronchi	Y	Outside
9	M < 15	Intact	30	0	Intense smoke inhalation with staining of the front of the teeth, and soot in the nostrils and nasal passages	Y	Outside
10	M > 21	Severely burnt	36	0	Soot in major airways	Y	Inside building
11	M > 21	Intact	42	0	Identifiable soot on the mucosal surface of the trachea just below the vocal cords	Y	Inside building
12	M > 65	Severely burnt	46	2.7	No sooting mentioned, severely burnt body	NA	Inside vehicle
13	M > 21	Severely burnt	67	0	No sooting mentioned, severely burnt body	NA	Not specified
14	M > 21	Severely burnt	69	0	No sooting mentioned, severely burnt body	NA	Inside building
15	M > 21	Intact	9	0	Focal area of soot staining within the larynx	Y	Outside
16	M > 21	Severely burnt	9	0	No sooting mentioned, severely burnt body	NA	Outside
17	F > 65	Severely burnt	55	0.5	No sooting mentioned, severely burnt body	NA	Inside building
18	M > 65	Intact	<5	NT	No immediate evidence of soot within proximal trachea	N	Outside
19	M > 21	Intact	<5	NT	Minimal soot deposition in tracheal lumen	Y	Outside
20	M > 21	Intact	<5	NT	No definite deposition of soot in the trachea	N	Not specified
21	M > 21	Intact	<5	NT	No soot staining of the lining of the larynx, trachea and major bronchi	N	Outside
22	M < 15	Intact	<5	NT	Soot in mouth, not in airways	N	Outside
23	M < 15	Intact	<5	NT	Nil soot in airways	N	Outside
24	M > 21	Intact	<5	NT	Nil evidence of soot inhalation	N	Outside
25	F > 21	Intact	<5	NT	Moderate amount of soot staining on the front of the teeth and in the airways including the trachea and major bronchi	Y	Outside
26	F > 21	Intact	<5	NT	No sooting mentioned, severely burnt body	NA	Outside
27	F > 21	Intact	<5	NT	Trachea shows no sooting	N	Outside
28	M > 15	Intact	<5	NT	No clear unequivocal soot material was identified within the trachea	N	Not specified
29	F > 65	Intact	<5	NT	Sooting within trachea	Y	Outside
30	M > 21	Intact	<5	NT	Moderate amount of soot in the airways extending into the trachea and major bronchi	Y	Inside vehicle

Note exact ages are not shown to protect identities. *Abbreviations*: Y = Yes, N = No, NA = not available, NT = not tested.

investigation service to the Victorian State Coroner. The latter is required by statute to investigate prescribed categories of the so-called reportable deaths and these include those that are sudden, unexpected, violent or unnatural (Coroners Act (Vic) 2008, S4).

Blood, in addition to other specimens, was collected by forensic technicians at VIFM under the supervision of the forensic pathologist according to standard mortuary procedures. Blood was stored in commercially prepared preservative tubes containing 1% (w/v) sodium fluoride/potassium oxalate and kept at 4 °C until analysis.

Carboxyhaemoglobin was measured by co-oximetry (ABL-700 Co-oximeter, Radiometer Copenhagen, Melbourne, Australia) and reported as a percentage of total hemoglobin. Whole blood hydrogen cyanide was analysed by HPLC/UV. Hydrogen cyanide was only measured in cases positive to COHb.

Table 2
COHb (median and mean) concentrations by location of deceased.

Concentration of COHb	Found outside	Found inside	Location not specified
Median [COHb]	16% (n = 9)	46% (n = 5)	29% (n = 3)
Mean [COHb]	19%	50%	39%

Blood was unavailable for sampling in severely burnt bodies and the blood collected from those who died in hospital was unavailable for analysis.

3. Results

Of 173 deceased victims only 30 (17%) were able to provide suitable[1] blood specimens for analysis.

The ages of these 30 deaths ranged from 3 to 80 years and there were 8 females and 22 males. 13 cases (43%) were considered negative (less than 5% COHb), 12 (40%) were between 5 and 40% COHb, 2 (6.7%) between 40 and 50% and 3 (10%) were greater than 50% COHb (Table 1).

There were 6 persons either found within a building or a car and the COHb in these cases ranged up to 69% (mean 50%). There were 5 cases where the location was unable to be determined as either indoor or outdoor due to the extensive nature of the fire. The remaining 19 deceased persons were all located outside in the

[1] "Suitable" blood specimens include blood that was still homogeneous and appropriate for toxicological analysis. There were many cases where blood received in the laboratory from collection at autopsy was charred and degraded to the point where it could not be analysed using our method of COHb determination.